CALIBRATION AND VALIDATION OF FREE SPEED SUBMODEL OF INDO-SWEDISH TRAFFIC SIMULATION MODEL

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By

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CERTIFICATE

This is to certify that the thesis "CALIBRATION AND VALIDATION OF FREE SPEED SUBMODEL OF INDO-SWEDISH TRAFFIC SIMULATION MODEL" submitted by Shri Abhijit Bhattacharjee in partial fulfilment of the requirements for the award of Master of Technology of the Indian Institute of Technology, Kanpur, is a record of bonafide research work carried out by him under my supervision and guidance. The work embodied in this thesis has not been submitted elsewhere for the award of a degree.

January ,1993

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ABSTRACT

The main objective of the research presented in this thesis is to calibrate Indo Swedish Traffic Simulation Model for free speed situation. The road submodel has been modified accordingly. Extensive validation of the free flow simulation have been carried out.

In the first phase major effort has been devoted in the study of free speed distributions of different types of vehicle. Free speed model, as a submodel of the main traffic simulation model, considers the effect of roadway parameters (i.e. width, curvature and roughness) on the basic desired speed (BDS). Models have been developed to compute the free speed of vehicles as function of roadwidth, curvature and roughness. The median basic desired speed, V_{0m} is reduced to a new median speed V_{1m}, where V_{1m} is a function of road width. Then V_{1m} is reduced to a new median speed V_{2m}, which is a function of both of the median speed without the horizontal curve, V_{1m}, and the radius of curvature. Now V_{2m} is reduced to a new median speed V_{3m} which is a function of surface roughness and median speed V_{2m}. After the median speed V_{3m} has been computed, a resulting new speed

distribution is calculated. This is obtained by transforming the basic desired speed distribution with the median value V_{0m} to the new median speed V_{3m} and at the same time rotating about V_3 so that the dispersion of the distribution decreases. A transformation measure, the Q value, indicates how far the basic desired distribution must be rotated about the new median value V_{3m}, is computed for each vehicle type.

The road submodel has been modified to calculate the median speed and transformation measure, Q value, for each vehicle type. The free flow simulation model is than validated for each vehicle type for different road geometry in plain and rolling terrain for the single lane, intermediate lane and two lane roads with varying horizontal curvature and roughness. The predicted free speed are found to be very close to those obtained in the field, thus proving the validity of the calibration of free flow simulation model. The model thus developed is capable of predicting accurately the free speed distribution of vehicles on any road stretches thus filling one of the gap existed in the Indo-Swedish Traffic Simulation Model.

CHAPTER I

INTRODUCTION

1.1 General

Transportation contributes to the economic, industrial, social and cultural development of any country. Among all modes of transportation, road transport is the most easily accessible mode available to people. The road network could alone serve the remotest villages of the country. Road transport has recorded a phenomenal growth in the wake of all round national development in the country. Hence there is a need for enhancing and upgrading the road network. This causes substantial pressure on the planners. In order to select the most beneficial scheme from among a number of alternatives, it is necessary to have an economic appraisal of various alternatives. Rational decisions will be required before undertaking such improvements. This necessitates the availability of reliable information regarding free speed, time delay, fuel consumption, accident rates and cost of maintenance and spare parts. Given the roadway and its

geometric features, the above mentioned factors form the function of speed and quality of flow on these highways.

1.2 Need for Road Development Planning

In the above framework there is an urgent need to develop rational tools to evaluate alternative investment programs. The investments on the proposed schemes are of very high magnitude. Budget and resource constraints forces us to closely examine the various costs and benefits associated with the investment programs such as construction costs, maintenance costs, benefits in the terms of user costs. Such a framework would enable the planner to select a project judiciously among the various investment programs under consideration.

1.3 Indian Road and Traffic Conditions

Indian roads comprise primarily of single lane, intermediate lane, two lane and four lane divided carriageways. The road with pavement width 3.5m are designated as single lane roads, while the roads of 5.5m wide are generally known as intermediate lane roads. 7m wide roads

are the two lane highways. The four lane divided carriageway roads are 14m to 15m wide, provided with median barrier. In general all the roads are provided with earthen shoulders on either side. Some times part of the shoulders of the single lane road has been improved with brick paving to increase the effective width of the roads to facilitate the ease of movement on these roads. The brick paving vary in width from about 0.5m to 1.6m. However, their condition is generally poor due to usage by heavy vehicular traffic. Since the strength of the shoulders is much lower, they deteriorate much faster when subjected to wheel heavierloading. Some times the difference in levels is as much as 10cm, at the interface between the pavement and the brick shoulders.

The road traffic on Indian roads is highly heterogeneous, being constituted by vehicle types as fast as Maruti cars and as slow as bullock carts. The fast moving vehicles include light motor vehicles, trucks and buses, trailer combinations and several categories of two wheelers. Amongst the slow moving vehicles, bicycles, cycle rickshaws and animal drawn vehicles dominate the scene. It has been observed that operating speeds of these vehicles are quite low even at low and medium traffic conditions. This

may be attributed due to poor surface conditions, road geometric, over loading of vehicles, vehicle conditions etc. The traffic on some sections of national highways has grown to such an extent that proposals for widening the two lane highways to four lanes are under consideration. The Government policy to develop some locations as industrial areas and the acute traffic congestion on many links has created the need for the construction of roads with superior facilities such as expressways. In addition to this, there are numerous proposals to widen some of the existing single lane roads to intermediate and two lane highways.

1.4 Earlier Work Done in India

Realizing the need for setting up certain design standards, evaluation of various project schemes and the necessity to create a database on various road conditions, traffic characteristics, a project Road User Cost Study (RUCS) was sponsored by the Government of India and the International Bank for Reconstruction and Development (World Bank). In order to evaluate the alternative investment policies, the road user cost study was carried out. The road user cost study in India dealt with only this component of

the total transportation cost.

Evaluation of traffic flow characteristics can be made in two ways: through analytical studies and simulation modeling. The simulation modeling project was taken up by the Indian Institute of Technology, Kanpur(IITK) in collaboration with the Swedish National Road and Traffic Research Institute(VTI). The study developed simulation models for single lane, intermediate lane, two and four lane conditions with extensive calibration and validation. The simulation models developed for the Indian traffic conditions for single lane, intermediate lane, and two lane roads consider the crossing of vehicles in opposite directions. These models were developed with Swedish model as their basis.

1.5 Indo Swedish Traffic Simulation model

This model is the modified version of the VTI model, originally developed in Sweden, to suit the road and traffic conditions prevailing in the Indian environment. On the basis of its application the model has been divided into two parts. One part simulates the speed of the freely moving vehicle

along the road "free flow traffic model" and another part simulates the interaction between the individual vehicles in the vehicle streams "interaction model".

1.5.1 Free Flow Traffic Model

The road stretch is represented in the model as a series of geometrically homogeneous road blocks. Within each block the factors of road width, radius of curvature, speed limits and gradients are kept constant. Each driver in the traffic simulation model is allotted a speed from the basic desired speed distribution(BDS). A driver unimpeded by traffic interactions chooses to travel at maximum speed on a wide, straight, horizontal road with no speed restriction and this is termed as basic desired speed(BDS)

The free block speed adopted by a vehiclein a particular road block is dependent on the median speed of the road block, transformation coefficient(Q value) and BDS of the vehicle. Apart from the block speed, the slope, if any, is also assigned to the block. Each vehicle has also been allotted a power mass(P/m) ratio, as well as air and rolling resistance, which together decides the ability to

reach or maintain this block speed on the particular slope. If the vehicle has a speed lesser than the block speed, when entering a block, or it cannot maintain its block speed due to the slope, its speed is calculated using Newton's equation for momentum.

The resulting speed is thus determined from a desired ability situation resulting in a speed profile along the road in which corrections have been made to the block speed with regard to P/m ratio of the vehicle to allow for the vertical profile of the road and the air and rolling resistances.

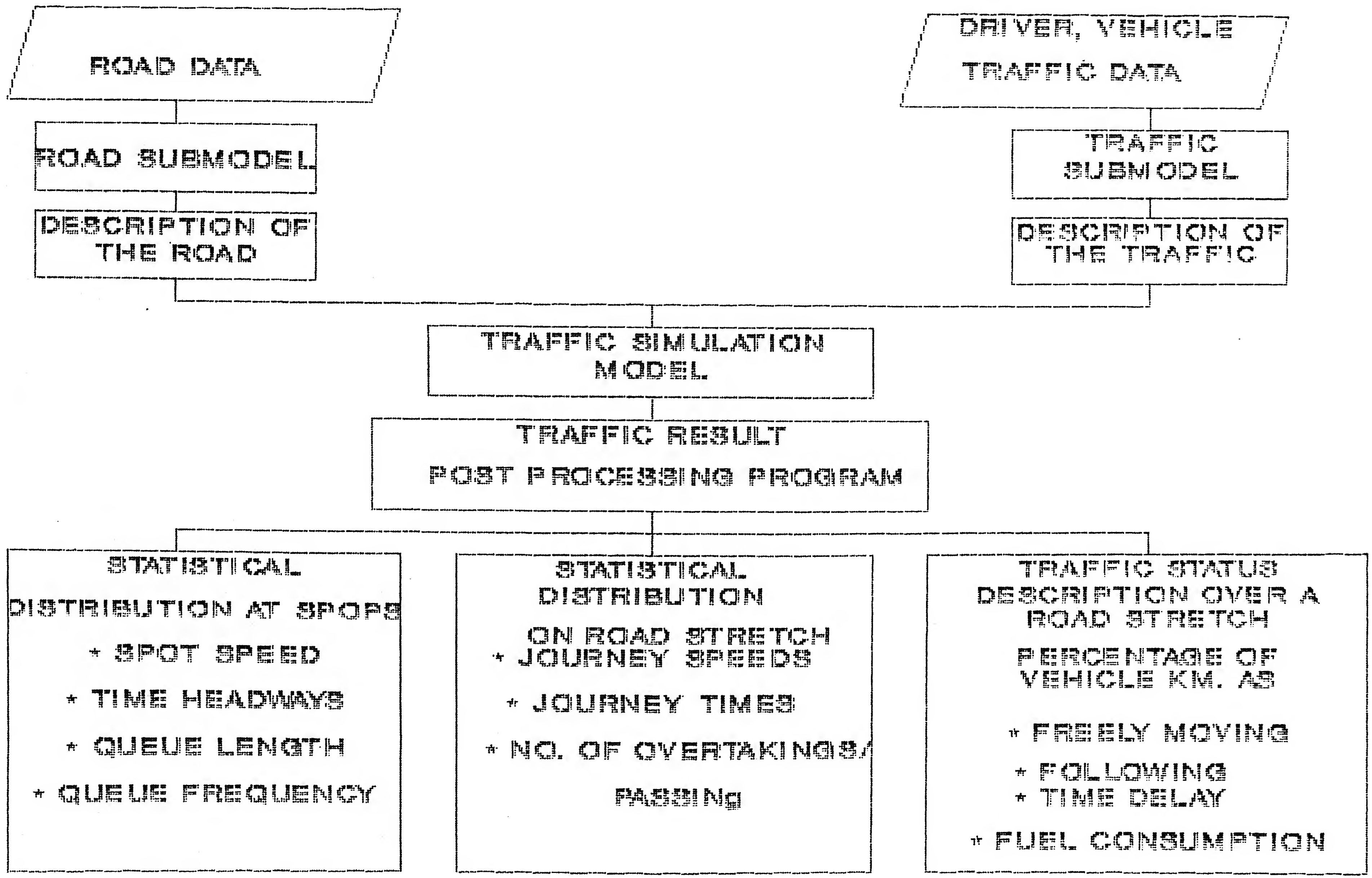
1.5.2 Interaction Model

The free vehicle model calculates how free vehicle adopts its speed to road width, alignment, gradient and speed limits. The interaction model takes into account the way in which individual vehicles are influenced by surrounding traffic. The speed of the vehicle in the traffic stream is influenced by the volume, composition and speed distribution of the traffic.

In addition to the speed and P/m ratio, each vehicle

is allocated a time and road coordinate for starting, a direction of travel and an initial entry speed. This permits the faster vehicles to catchup with slower vehicles along the road and leads to overtaking or following. The overtaking has been divided into flying, accelerating and passing. If overtaking starts as soon as one vehicle catches up with another vehicle, flying overtaking take place. If overtaking occurs after following, an accelerated overtaking is carried out. If the road has a wide shoulder of good quality overtaking can also take place by passing, which means that the leading vehicle moves with certain probability on to the shoulders. When following occurs, the vehicle follows the preceding vehicle with a constant time headway depending on the preceding vehicle type.

In addition to the free movement, vehicle meet each other in opposing directions, decelerate to safe crossing speeds and cross each other. Two opposing vehicles are interacting with each other due to the width of the road on single lane and intermediate lane roads. On these roads vehicles have to yield space and slow down, if the two vehicles involved in crossing are wide. Under Indian conditions it is more important to consider crossing,



ROAD DATA
ROAD SUBMODEL
DESCRIPTION OF THE ROAD
DRIVER, VEHICLE
TRAFFIC DATA
TRAFFIC SUBMODEL
DESCRIPTION OF THE TRAFFIC
TRAFFIC SIMULATION MODEL
TRAFFIC RESULT
POST PROCESSING PROGRAM
STATISTICAL
DISTRIBUTION AT SPOPS
* SPOT SPEED
* TIME HEADWAYS
* QUEUE LENGTH
* QUEUE FREQUENCY
STATISTICAL
DISTRIBUTION
ON ROAD STRETCH
* JOURNEY SPEEDS
* JOURNEY TIMES
* NO. OF OVERTAKINGS/
PASSING
TRAFFIC STATUS
DESCRIPTION OVER A
ROAD STRETCH
PERCENTAGE OF
VEHICLE KM. AS
* FREELY MOVING
* FOLLOWING
* TIME DELAY
* FUEL CONSUMPTION

Fig. 1.1.

since speeds are calculated based on roadwidth, shoulder type and its quality and vehicles type involved in crossing.

1.5.3 Program System for Traffic Simulation

The simulation program comprises the heart of a program system as shown in the Figure 1.1. The simulation model is a model system permits computation of the following detailed events:

a) Simulation of the behaviour of free flow traffic in both directions, i.e., vehicle speed profile'sdependence on road attributes, speed limits in force on vehicle attributes, but excluding the interdependence of other vehicles in the traffic stream.

b) Simulation of the behaviour of vehicles which also takes into account of the interdependence of surrounding vehicles in their own and opposite direction.

1.5.4 Road submodel

The objective of this model is to represent the road as a series of geometrically homogeneous road blocks and to create a speed profile along the road for each free moving vehicle. Thus a road block will be of constant road width, curve radius, gradient, speed limit and roughness. The speed profile depends on road geometry and speed limit. The median speed for each block V_{3m}, is a function of the distribution of BDS, road width, horizontal curve, and the roughness. In addition a transformation measure, the Q value for each road block is calculated, which indicates how far the BDS distribution must be rotated about the median speed V_{3m} to obtain the free speed distribution.

1.5.5. Traffic Submodel

The traffic submodel describes the traffic characteristics provided as data input to the simulation model. Traffic in the simulation model is represented by number of driver vehicle(DV) units. A DV unit contains the characteristics to model the driver behaviour as well as the vehicle parameters. The traffic is made up of fast as well as

slow moving vehicles. Vehicles vary widely in their size, power to mass ratio, operating speed and other characteristics such as vehicle age and condition. The attributes of a DV unit are

a) Identification number.

b) Vehicle type.

c) P/m ratio

d) Basic desired speed.

e) Origin.

f) Destination.

g) Entry time

h) Entry speed.

Every DV unit in the simulation model is uniquely represented by an index called identification number. Associated with each DV unit are the vehicle parameters, vehicle type and P/m ratio(p-value). The p-value is a significant factor contributing to the performance capability of the vehicles. Lower p-value limits the ability of a vehicle to climb the grades thereby affecting the capacities of the road stretches considerably.

1.6 Problem Statement and Object Of Study

It has been observed that different vehicle types have different BDS distributions and the variation between the BDS distributions is appreciable. Specifically in the case of Indian traffic, it is necessary to consider the median block speed and Q value separately for each vehicle type. Thus it has been decided to calibrate the Q value for ten different vehicle types under different road condition and geometry. Once the calibration of Q is done, the necessary modification in the road submodel is carried out and an extensive model validation for free speed simulation is performed.

Therefore, the main objective is to calibrate Q value for ten different vehicle types from the field data collected by the Central Road Research Institute(CRRI) Delhi. The second step is the modification of the road submodel and validation of the simulation model for free speed condition.

1.7 Organization of the Thesis

The thesis is presented in six chapters. Chapter II

presents the detailed description of the Indo Swedish Road Traffic Simulation model, traffic submodel and road submodel. A brief description of the models are present in this chapter.

Chapter III explains in detail the model for free speed prediction. Calibration of various parameters involving VTI free vehicle model are explained in this chapter. This chapter also explains the derivation of polynomials for free speed prediction.

Chapter IV explains the free speed modeling and calibration of Q values. Free speed distributions generated using the calibrated Q values are also shown in this chapter.

Chapter V explains the various inputs to the road submodel, experiments with the road submodel and validation of the model. The comparison between the field and simulated data are done in this chapter.

Chapter VI presents the summary of the present work, scope of the study and conclusion drawn from the study.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 General

The detailed description of the Indo Swedish Traffic Simulation Model for narrow, intermediate and two lane roads is presented in Section 2.2. The traffic behaviour in the simulation model considering overtakings are given in Section 2.2.3. The detailed description of road submodel covering from calculation of median speed to the transformation coefficient(Q value) are given in section 2.3 The generation of traffic from calibrated distributions using traffic submodel is presented in Section 2.4.

2.2 Indo Swedish Traffic Simulation Model

A stochastic discrete event simulation model was developed by the VTI for the two lane bi-directional traffic system during the period 1965 to 1977. It has a long history of calibration and validation over a number of road stretches in Sweden. Subsequently, the model has been used for traffic analysis in providing auxiliary lanes in Finland

and United Kingdom. While RUCS study was initiated in India, the need to develop a simulation model for the Indian road and traffic conditions was felt. Accordingly, an evaluation of several models existing before 1980 led to the conclusion that the best available and reliable model was the one developed by VTI. This model formed the basis for work done subsequently at the Indian Institute of Technology, Kanpur in collaboration with the scientists of VTI. The version of the model is currently known as the Indo-Swedish Traffic Simulation Model.

The traffic and road condition prevailing in India are too complex to model by simple approaches. It is necessary to incorporate the heterogeneity of traffic and the hosts of road widths along with shoulders condition. The basic structure of the VTI model is such that it had built in features that allowed the restructuring of the model for Indian conditions.The program and the data structures are based on the Jackson Structured Programming(JSP) technique and has been programmed in one of the highest level of languages - SIMULA67 The main program principle of SIMULA is pseudo parallel execution which can be regarded as a further development of event control of dynamic sequences. The model has been calibrated and validated extensively for the single,

2.2.1 General Program Design

The program mainly consists of two processes, which also contain the data and procedures. They are

1. Process class generator process
2. Process class vehicle

The vehicle generator process creates the driver vehicle objects and allots the individual driver-vehicle attributes. Here they are also allotted their traffic attributes. Parameters which define the vehicle are identification number, basic desired speed and power mass ratio. Parameters giving their traffic attributes are origin of the vehicle, destination of the vehicle, entry time and entry speed. The vehicle generator process also activates vehicles at their starting times.

The vehicle process describes all possibilities for action that a particular vehicle can have, for example "drive as freely moving vehicle" , "follow another vehicle", "overtake the vehicle in front","change to another track" etc. The freedom of choice covers mainly the set of alternatives that any vehicle can have, and the actions are assumed to occur

momentarily at calculated times. At each event the model data is updated and a particular event generated from among the possible event types. A note of the predicted event is inserted inserted chronologically and logically in a two way linkedlist and the events are then executed in this order.

The ordinary cycle for an arbitary vehicle is:

1. Predict the time of the next event - PREDICTNEXTEVTIME
2. Wait for the predicted time - HOLD
3. Move the vehicle in time and space - DRIVE

During the phase one of the cycle PREDICTNEXTEVTIME(predict next event time), PREDBLOCKBORDERTIME(predict time of passage of next blockborder), AVERSP(speed from preceding event to next event) and PREDICTBLBORDERSP(predict speed at passage of next block border) are calculated in their corresponding procedures. During phase three of the cycle the procedure DRIVE updates the attributes LOCALTIME(time of preceding event), LOCALCOORD(road coordinate at preceding event), AVERSP, PREDBLBORDERTIME(predicted time of passage of next road block border), and PREDECTBLBORDERSP(predicted speed at passage of next road block border).

During the phase two of the cycle it may happen that an adjacent vehicle interacts with the current vehicle with the result the predicted time of the next event for this vehicle is shown incorrect, since it will occur earlier. Its ordinary cycle consequently isinterrupted and the current vehicle considers that a surprise has occurred through the SURPRISE procedure. A prediction of new earlier event time for the vehicle is then made.

In the program the stretch of the road consists of a sequence of consecutive road block objects and a sight distance function in each direction of travel. Each road block object is homogeneous with regard to the roadwidth, slope, horizontal curvature, roughness, speed limit and overtaking restriction. The road block is represented in the program as an object from the Link class Roadblock. The object has the following important attributes :

- -RCO coordinate of the roadblock
- -RBLLENGTH road block length
- -ROADWIDTH road width class
- -LANE occurrence of auxiliary lane/ lateral space
- -RI slope
- -RCURVE radius of curvature
- -ROUGHNESS roughness of the road
- -RQ Q value with respect to normal speed

-IR block median speed

-DVQ IR^{RQ} - (median speed of the vehicle)^{RQ}

-CR block cross median speed

-CQ Q value with respect to crossing speed

-CVQ CR^{CQ} - (median crossing speed of the vehicle)^{CQ}

CQ, CVQ and CR are considered for accounting the traffic behaviour on narrow roads.

2.2.2 Representation of Traffic Behavior

Figure 2.1 shows the representation of lanes across the road width. A vehicle unimpeded by other traffic normally chooses to travel in lane 2. Thus lane 2 is used when driving under normal conditions whereas lane 3 is used while yielding to a faster vehicle from behind, and lane 1 is used while overtaking a slow vehicle. When vehicle P is caught up behind by a faster vehicle, Q, in lane 2 then P would move on to lane 3 with certain probability so that, the catching up vehicle could pass P in lane 2 (Fig 2.2).

When the catching up vehicle Q is not allowed to pass in its normal lane, i.e., when a paved shoulder is not present, or when P rejects to move on to the shoulder(if shoulder exists), Q would look for a gap in lane 1 and starts overtaking without having to reduce its speed. This is termed

as "flying overtaking". Figure 2.3 shows the steps involved in flying overtaking. When the gap available in lane 1 is not acceptable by the caught up vehicle Q, then it prepares to follow P at a safe distance. When an opportunity to overtake is accepted then Q moves to lane 1 for an accelerated overtaking. Thus, lane 1 is normally used for overtaking maneuvers, lane 2 when unconstrained by other traffic or while following a vehicle in front, and lane 3 to allow a faster vehicle catching up from behind to pass in lane 2. This logic with some modifications has been applied for single lane, intermediate lane and two lane bi-directional movement simulation.

Each vehicle has been allotted a "head" and a "tail". The driving rule in this model tries to maintain a minimum gap between any two vehicles, in the same lane. In order to ensure that this gap is maintained, the head length and tail length are defined for each vehicle as follows.

$$\text{Headlength} = \frac{(V_{forward} - V_{follow})^2}{2 * \text{Deacc}} \qquad (2.1)$$

$$\text{If } V_{forward} < V_{follow}$$

$$= 0 \text{ otherwise}$$

$$\text{Taillength} = Th_{follow} * V_{follow}$$

where $V_{forward}$ is the speed of the preceding vehicle.

V_{follow} is the speed of the following vehicle.

Th_{follow} is the time headway of the following vehicle.

Deacc is the retardation rate.

Head length therefore indicates the distance required to slow down with the given retardation rate to the speed of the preceding vehicle. The tail length is chosen so that vehicles in queue are separated by given time intervals.

As shown in Figure 2.1 a roadstretch is divided into homogeneous blocks. Each block has median speed IR, Q value and RQ in addition to other attributes. In the case of narrow roads median cross velocity(CR), Q value for cross velocity and CVQ for each block are also present. The DVQ and CVQ are calculated as explained in section 2.2.1.

When a vehicle enters a block its free block speed and in the case of narrow roads free block and its free cross speeds are calculated by using the following formulae:

$$\text{Free block speed} = (VON^{Q} + DVQ)^{1/RQ} \qquad (2.2)$$

$$\text{Free cross speed} = (CON^{CQ} + CVQ)^{1/CQ} \qquad (2.3)$$

where VON is the basic desired speed of the vehicle

CON is the median crossing speed of the vehicle

A numerical integration of the power equation over time is applied to determine the speed and time of reaching the block border. The procedure continues till the free block speed has been exceeded or block border has been reached (Fig. 2.4)

2.2.3 Probabilities of Overtaking

The drivers desire to perform an overtaking operation with a given free sight distance is determined in the model by a set of stochastic functions. The probability of accepting a free sight distance of a given length when opportunity for overtaking is offered, depends on different overtaking situations as described below:

Type of overtaking	1. flying
	2. accelerating
Sight limitation	1. oncoming vehicle
	2 natural obstruction
Overtaken vehicle	1. vehicle type
	2. speed of the overtaken vehicle
Roadwidth	1. hard shoulder > 2m, corresponding to a paved road width of 11m.
	2. others

The probabilities are given by

$$p(x) = 0 \quad \text{if } x <= S1m.$$
$$= a(x-S1)/(S2-S1) \quad \text{if } S1 < x < S2m \qquad (2.4)$$
$$= others \quad \text{if } S2 <= x$$

where x is a free sight distance and a,S1,S2 are calibration constants.

In addition, if the vehicle is in platoon, the probability is reduced as follows :

$$P_{red} = p*k(\text{place in platoon} - 1) \qquad (2.5)$$

where P_{red} is the reduced probability

p is obtained from the equation 2.4

k is model constant at present it is set to 0.75

2.3 Road Submodel

This model creates the road as a series of homogeneous road blocks and the variation of sight distance along the road, as input to the simulation program. In the simulation model each vehicle has an essential characteristic, i.e. its BDS. This is the speed at which the driver would chose to travel on a wide straight horizontal road with no speed limit, i,e, "free speed". Brodin and Carlsson (1983)(Ref.3) described free speed as a function of road geometry and BDS, which formed the basis for the VTI model and Indo-Swedish

Traffic Simulation Models . The road submodel described by Brodin and Carlsson is explained in this chapter. This is modified to a more general form and is explained in the next Chapter.

It is assumed that for a straight horizontal road having width of 12m. or more, there is aBDS distribution and from that vehicle chooses to travel at a speed known as its BDS. The vehicle is prevented from maintaining its BDS by the following factors:

* a road width less than 12m.
* curves with a radius of less than 1000m.
* speed limit
* upward gradients.

Effect of Roadwidth:

For a roadwidth under 12m. the median basic desired speed V_{0m} is reduced to a median speed V_{1m}. It is assumed that roads with over 7m paved are built with a carriage way 7m wide, the remaining width consists of two hard shoulders. For a roadwidth less than 7m it is assumed that no hard shoulders are provided.

The median speed V_{1m} is given by:

$$\frac{1}{V_{1m}} = \frac{1}{V_{Om}} + \frac{a}{(v_b - 2.5)} - \frac{a}{4.5} \qquad (2.6)$$

where v_b is the road width in m

a is the calibration constant

V_{Om} is the median speed for 7m. road width.

Effect of Horizontal Curves:

If a road includes a horizontal curve, the median speed V_{1m} must be reduced taking into account the horizontal radius. Curves with mean radius r > 1000m. do not effect the speed V_{1m}. If r <= 1000m. the median speed V_{2m} on the curve is obtained by the following expression, where speeds V_{2m} and V_{1m} are given in m/s.

$$V_{2m} = \frac{1}{\mathrm{SQRT}\left(\left(\frac{1}{V_{1m}}\right)^2 + b\left(\frac{1}{r} - 0.001\right)\right)} \qquad (2.7)$$

where r is the mean radius in meter

b is the calibration constant.

V_{1m} is the median speed on straight road.

From the equation it is observed that, entry speed V_1

small radius curves constant bcon has the gratest effect.

Effect of surface roughness:

For surface roughness, the median speed V_{3m} is obtained with the following expression:

$$V_{3m} = V_{2m} * (e^{-c*Rg}) \qquad (2.8)$$

where Rg is the surface roughness

c is the calibration constants

After the median speed, V_{3m} has been calculated, the resulting distribution V_3 must be determined. A transformation measure, Q, indicates as to how far the basic desired speed distribution must be rotated about the median speed V_{3m}. The Q value is a function of the median speeds V_{0m}, V_{1m}, V_{2m} and V_{3m}. The free speed distribution V_3, using the Q value transformation is determined as follows:

$$V_{0i}^{Q} - V_{3i}^{Q} = V_{0m}^{Q} - V_{3m}^{Q} \qquad (2.9)$$

in basic desired speed and free speed distributions respectively.

If Q = 1 then the above equation results in a purely parallel shift indicating a constant reduction in speed for fast moving as well slow moving vehicles.

However, when $Q < 1$ the free speed distribution, V_3, is rotated in anticlockwise direction showing that a driver with a higher BDS reduces his speed more than a driver with a lower BDS when influenced by speed reduction factor. It must be noted that the smaller the value of Q, the larger will be the rotation.

Each of the factors of the road width, horizontal curve and speed limit has its own isolated measure of rotation, termed q.

This factors are:

q_1 for road width

q_2 for horizontal curve

q_3 for speed limit

All values of $q_i < 1$

The total measure of transformation, Q, is a function of q_i with median speed V_{1m}, V_{2m} and V_{3m} included as weighing factors

$$Q = \frac{q1\ k1 + q2\ k2 + q3\ k3}{k1 + k2 + k3} \tag{2.10}$$

where $k_1 = V_{0m} - V_{1m}$

$k_2 = 2*(V_{1m} - V_{2m})$

$k_3 = 2.5*(V_{2m} - V_{3m})$

Hence Q is the weighted mean of q_1,q_2 and q_3

Speed profile for the median vehicle:

The road to be simulated is described as a series of homogeneous blocks. Within each block, the factors of road width,curve radius, surface roughness and also gradient are constant. Thus V_3 is constant within each block. If any road factor is altered, a discontinuity in the speed profile results. Consequently, retardations and accelerations between these blocks are treated as follows:

If the median speed V_{3m} in block k is greater than the median speed V_{3m} in block k+1, the vehicle is retarded in block k until the next median speed is reached at the block limit. A new block limit is created where the retardation begins.

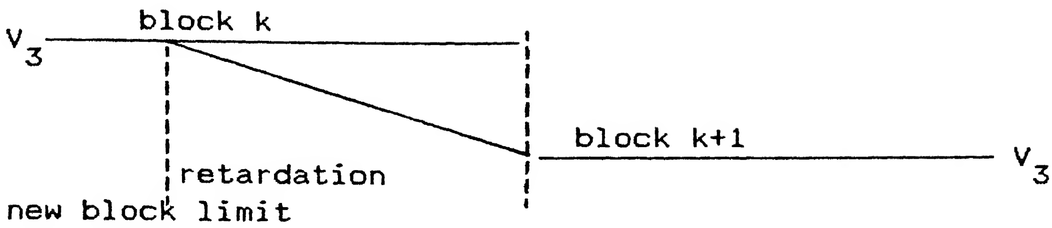


Fig.2.5

On the other hand, if speed V_{3m} is less in block k than k+1, the vehicle accelerates in block k+1 to the true median speed V_{3m}. This acceleration takes place with a special speed model, the p-model, described in the next section.

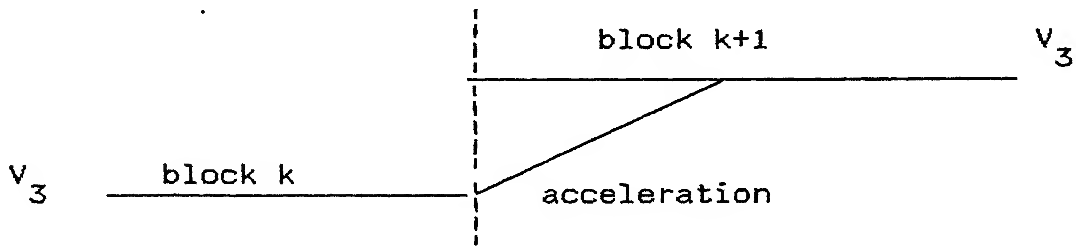


Fig.2.6

At each retardation, but not acceleration, a new block is created, termed the influence block. The length of this influence block is obtained as follows:

K,k+1 are the block number. $V_{3m,k}$ and $V_{3m,k+1}$ are the corresponding desired median speeds, calculated in m/s. In the influence block, the retardation r is constant. The length L of the influence block is then given by the motion

$$r = \frac{V_{3m,k+1}^2 - V_{3m,k}^2}{2L} \quad m/s \qquad (2.11)$$

The r value is taken as 0.5 m/s^2. This corresponds approximately to the retardation a vehicle receives when the driver releases the accelerator pedal. This gives

$$L = V_{3m,k}^2 - V_{3m,k+1}^2 \qquad (2.12)$$

According to the magnitude of L, the length of the influence block is chosen as follows:

$$L_{inf} = \begin{cases} L & (L >= 25m) \\ 25 & (13 <= L < 25m) \\ 0 & (L < 13m) \end{cases} \qquad (2.13)$$

If L < 13m, a retardation is obtained within block k+1, but this error is insignificant.

2.4 Traffic Submodel

This model assigns the vehicle characteristics(identity number, basic desired speed and P/m ratio) as well as traffic characteristics(starting point, starting time and destination). This model was originally developed by Clive Gilliams of U.K Department of Transport(Ref.2). The current

model is the modified version. The distribution of vehicles among the various classes (i.e., cars, trucks,scooters etc.) is to be specified in the input data. The procedure for generating the vehicle as well as traffic parameters is explained below.

Identification Number: This is trivially generated by incrementing each time a vehicle is generated to enter the simulated road stretch at the specified coordinate.

Vehicle type: A distribution of vehicle types is specified for the anticipated traffic composition. The vehicle type of an individual vehicle is obtained from the distribution.

Basic desired speed: The vehicles are uniformly distributed over the basic desired speed distribution for each vehicle type as specified in the input. It generates the BDS from the given distribution.

Power to mass ratio: The power equation can be obtained as follows.

Consider a vehicle on the upgrade. Figure 2.6 shows the various forces acting on the vehicle. The force equation gives

$$m\ a = F - F_r - F_L - mg * \sin(i)$$

$$(2.14)$$

where m = mass of the vehicle in Kg.

a = acceleration in m/s^2

F = tractive force in Newtons

F_L = air resistance in Newtons

F_r = rolling resistance in Newtons

g = gravitational acceleration in ms^{-2}.

i = gradient in m/km

V = vehicle speed in m/s

t = time in s

The tractive force at the wheel can be written as

$$F = P/V \tag{2.15}$$

where P is the power available, measured at the wheels in Watts and V is the speed in ms^{-1}.

The air resistance is expressed as

$$F_L = C_L A V^2 \tag{2.16}$$

where C_L is an air resistance coefficient in kg/m^3

A is the frontal area in m^2

The rolling resistance F_r is expressed as

$$F_r = m \cos(i) * (C_{r1} + C_{r2} V) \tag{2.17}$$

$$= m\,(C_{r1} + C_{r2}V)$$

C_{r1} and C_{r2} are rolling resistance coefficients.

The gravitational force is expressed as

$$m\,g\,\sin(i) \simeq m\,g\,i \qquad (2.18)$$

Substituting the above expressions in force equation, we get

$$m\,\frac{dv}{dt} = \frac{P}{V} - C_L A V^2 - m(C_{cr1} + C_{cr2}) - mgi$$

dividing by m we get

$$\frac{dv}{dt} = \frac{p}{V} - \frac{C_L A}{m}\,V^2 - (C_{r1} + C_{r2}V) - gi \qquad (2.19)$$

where $p = \frac{P}{m}$ is the power/weight ratio used for the vehicle (p-value)

The equation is solved numerically by conversion to a difference equation

$$\frac{dv}{dt} \sim \frac{\Delta V}{\Delta t} = \frac{p}{V} - \frac{C_L A}{m}\,V^2 - (C_{r1} + C_{r2}V) - gi \qquad (2.20)$$

Speed is thus calculated as follows

$$V_{n+1} = V_n + \Delta V_n \qquad n = 0,1,2\ldots.$$

$$\Delta V_n = \Delta t\left[\frac{p}{V_n} - \frac{C_L A}{m} V_n^2 - (C_{r1} + C_{r2} V_n) - gi \right] \quad (2.21)$$

And distance covered is

$$S_{n+1} = S_n + \Delta S_n \quad (2.22)$$

$$\Delta S_n = 0.5 \cdot \Delta t (V_n + V_{n+1})$$

Time stage Δt is chosen as

$$\Delta t = 0.015 \left| \frac{V_0}{a_0} \right| \quad (2.23)$$

before iteration is started.

Where V_0 is the entry speed in the block

a_0 is the acceleration at this speed

$$a_0 = \frac{p}{V_0} - \frac{C_L A}{m} V_0^2 - (C_{r1} + C_{r2} V_0) - gi \quad (2.24)$$

So that the time stage Δt is not too large for small a_0, it is limited to the same value as for travelling half the block length

$$\Delta t_{max} = \frac{\text{block length}}{2\ V} \quad (2.25)$$

In this way, at least two iterations are obtained in each block.

Entry time: The entry time for each vehicle entering the simulated road stretch is generated using the Shchul's(1955) composite time headway model. The usual form of the composite distribution is

$$f(t) = (1-\alpha)*g(t) + \alpha*h(t) \tag{2.26}$$

where f(t) is the probability density function of the composite headway distribution, g(t) is the probability density function of the headway distribution for free moving vehicle, h(t) is the probability density function for constrained vehicles, and α is the proportion of the constrained vehicles. Branston (1976) who analyzed the constrained time headway on the two lane roads in Indiana, USA, found that a lognormal distribution fitted the data with a mean of 2 seconds and a standard deviation of logarithms of constrained headways σ_c of 0.4. The time headway distribution of free moving vehicles is determined by platoon length, n. The total headway for a platoon length n is the sum of the one headway for the free moving platoon leader and (n-1) mean headways for the constrained vehicles. The mean time headway for the stream can be expressed as

$$\frac{\mu}{q} = \mu_f + (\mu - 1)\,\mu_c \tag{2.27}$$

where μ is the mean of the platoon size, q is the traffic flow in veh/h and μ_f and μ_c are the mean time headways for free and constrained vehicles respectively. A two parameter distribution due to Miller(1974) has been used for the generation of platoon size. The distribution of a platoon size r is defined as

$$pr = \frac{(s + r - 1)}{(m + s + r + 1)} \qquad \text{if } r > 1 \qquad (2.28)$$

$$= \frac{(m + 1)}{(m + s + 2)} \qquad \text{if } r=1 \qquad (2.29)$$

Miller (1965) found that μ may be estimated by using the equation

$$\mu(est) = 0.58 + 1.58 * z \qquad (2.30)$$

$$\text{where } z = \frac{0.1 * q}{\lambda\ (1 - q * \mu_c)} \qquad (2.31)$$

where λ is the overtaking rate for constrained vehicles. Now, the problem of estimating the M_u is reduced to that of estimating λ for a given road traffic flow. Miller (1963) used data collected on a single straight two lane road in Sweden to produce the estimate

the oncoming flow is assumed to be the traffic flow given as input, q.

Entry speed : For a free vehicle the entry speed is taken to be equal to 0.85*BDS . In the case of a constrained vehicles, the minimum BDS among the platoon is calculated (BDS_{minpl}) and 0.85 * BDS_{minpl}, is assigned as the entry speed of all the vehicles in the platoon. However, all these speeds are constantly reassessed once the vehicle enters the road stretch to be simulated. Hence entry speeds assigned are comparatively less important.

Detailed description of the existing traffic simulation model, road submodel and traffic submodel is presented in this chapter. The models for free speed prediction are presented in the next chapter. Chapter IV explains the calibration of Q values for different vehicle types. Chapter V explains the various experiments carried out for validation of the simulation model.

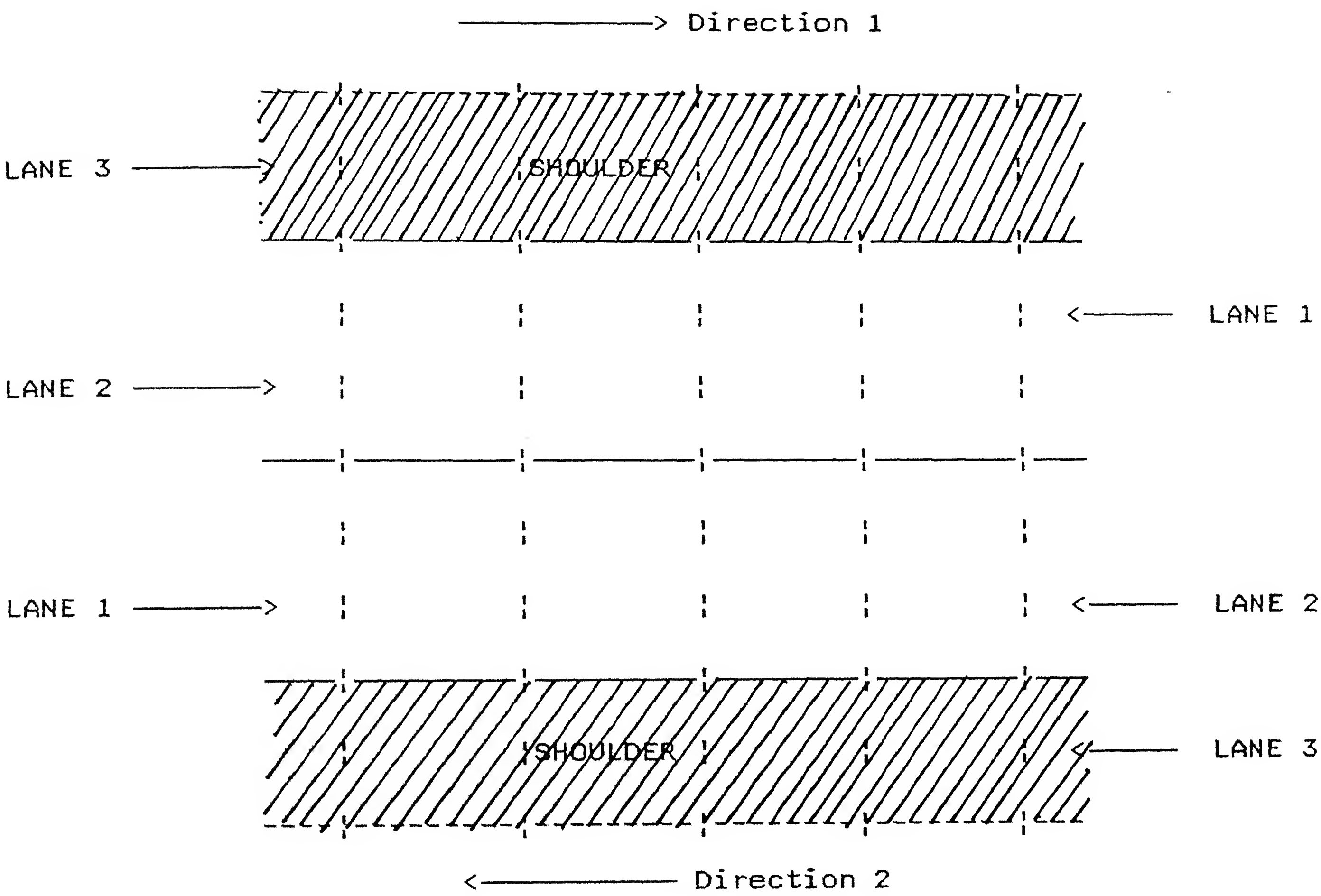
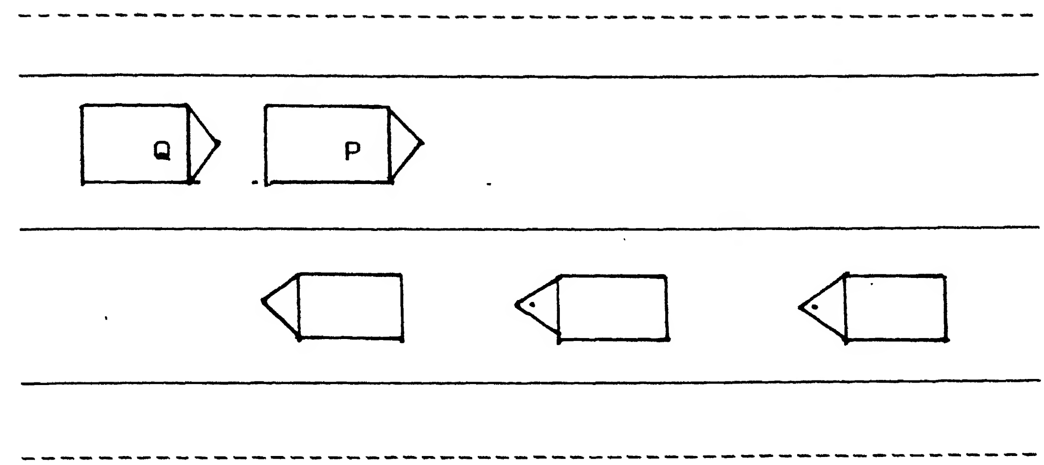
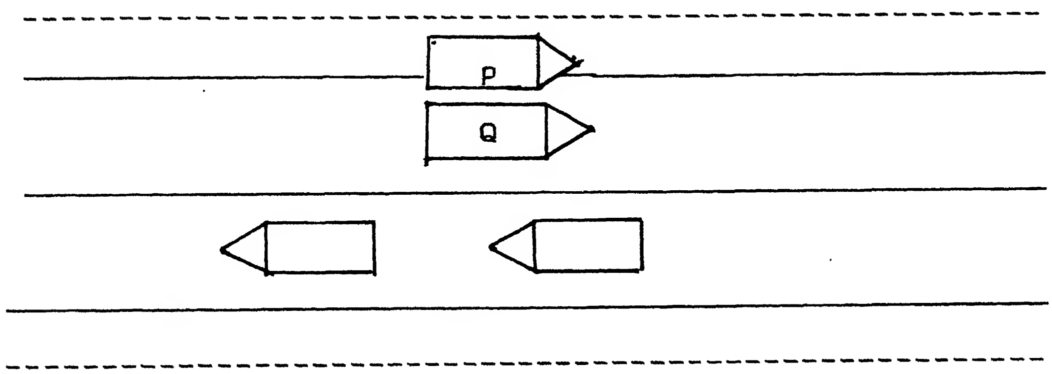


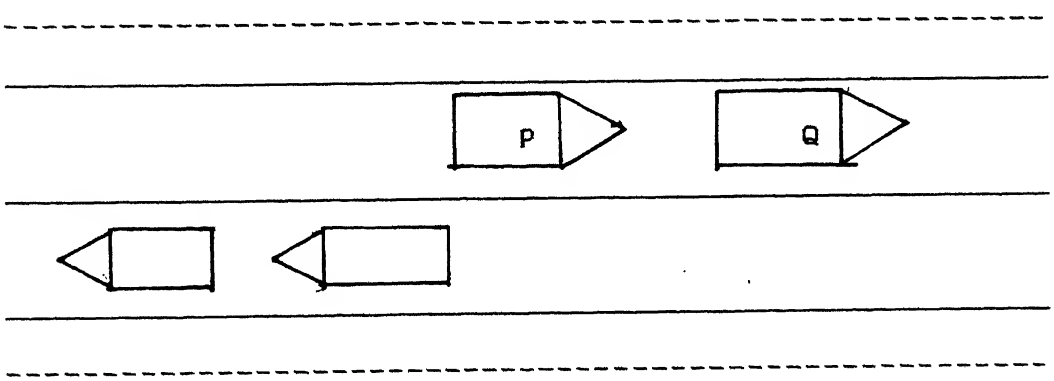
FIG 2.1 Pesentation of road in Indo-Swedish Taffic Smulation Mdel



(a) Vehicle Q catching up with P

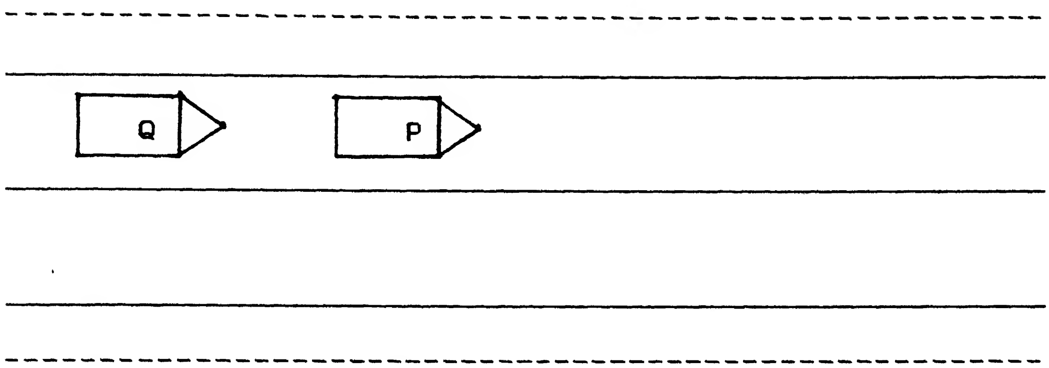


(b) Q Passing P

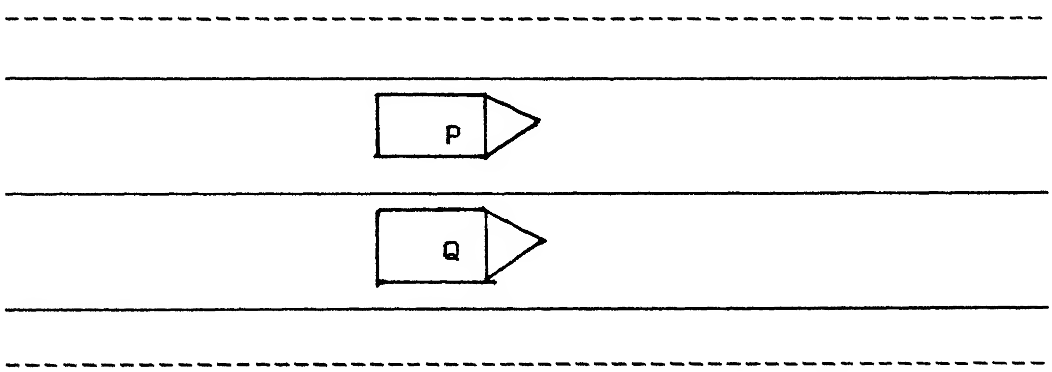


(c) Passing completed

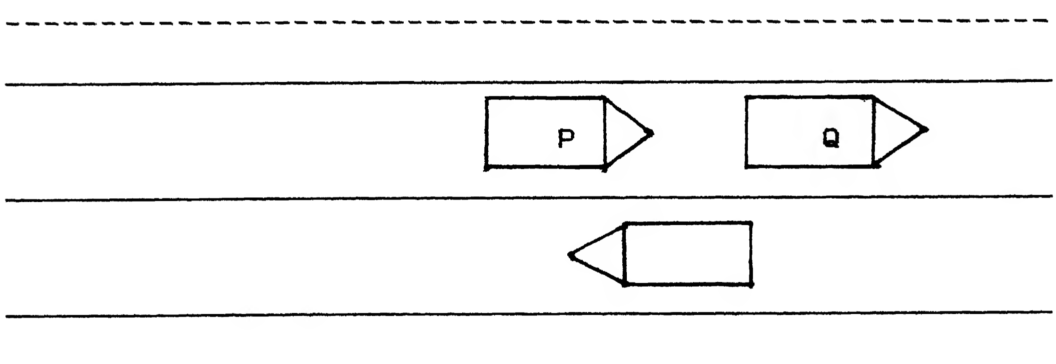
FIG. 2.2 Pssing manoeuvre described in Indo-Swedish



(a) Vehicle Q catching up with P



(b) Q Fly overtaking P in lane 1



(c) Flying overtaking compleated

FIG. 2.3 Flying overtaking procedure described in

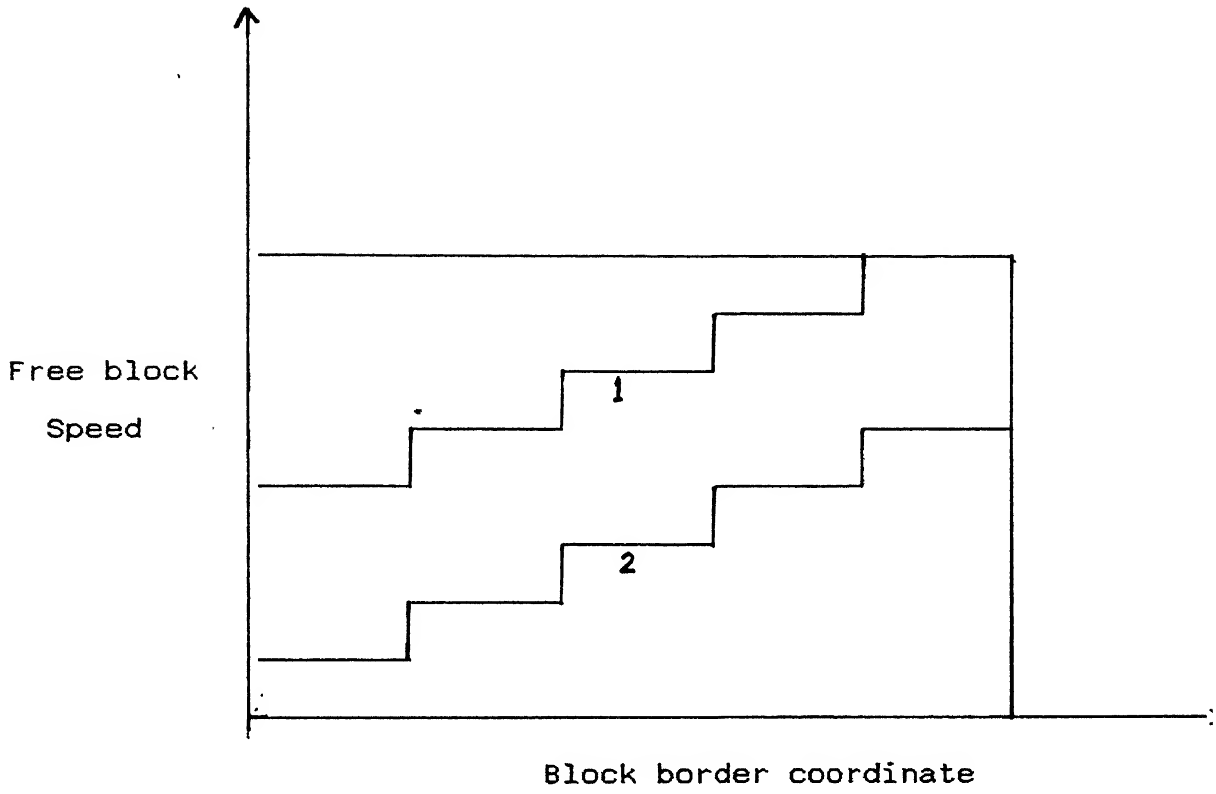


Fig 2.4 Numerical integration of power equation to obtain time of reaching the block border and speed for a free moving vehicle

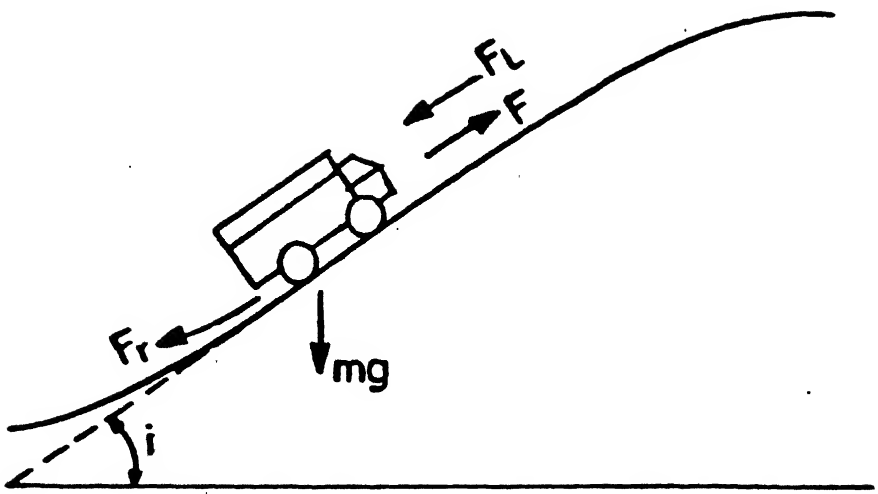


Fig. 2.5 Forces acting on a vehicle on an upgrade

CHAPTER III

MODEL FOR FREE SPEED PREDICTION

3.1 General

Free Speed model, as a sub model of the main Traffic Simulation model, considers the effect of roadway parameters (i,e, width, curvature, roughness, gradient etc) on the basic desired speed(BDS). Thus study of BDS and Free Speed of different types of vehicles becomes essential, as a prime input for the traffic simulation model.

A driver may not always be able to drive his vehicle at the basic desired speed (BDS) because of certain constraints like inadequate road geometry, riding quality of pavement and traffic flow conditions. The speed of the operation of any vehicle is governed by factors like roadway, traffic and other factors such as driver behaviour and vehicle characteristics (make and model).

The spot speed of any vehicle at any particular location depends upon a number of factors such as :

* Road factors (road geometry, road surface characteristics etc).

* Traffic factors (Traffic intensity, traffic composition etc).

TABLE NO.3.1

FRAMEWORK FOR FREE SPEED MEASUREMENT

ROAD TYPE		SINGLE LANE			INTERMEDIATE LANE			TWO LANE			FOUR LANE		
ROUGHNESS mm/Km.		LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THEN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000
TERRAIN	RADIUS OF CURVATURE (METERS)												
PLAIN	LESS THAN 150	FSC 111	FSC 121	FSC 131	FSC 211	FSC 221	FSC 231	FSC 311	FSC 321	FSC 331	FSC 411	FSC 421	FSC 431
	BETWEEN 150 AND 300	FSC 112	FSC 122	FSC 132	FSC 212	FSC 222	FSC 232	FSC 312	FSC 322	FSC 332	FSC 412	FSC 422	FSC 432
	BETWEEN 300 AND 450	FSC 113	FSC 123	FSC 133	FSC 213	FSC 223	FSC 233	FSC 313	FSC 323	FSC 333	FSC 413	FSC 423	FSC 433
	MORE THAN 450	FSC 114	FSC 124	FSC 134	FSC 214	FSC 224	FSC 234	FSC 314	FSC 324	FSC 334	FSC 414	FSC 424	FSC 434
	STRAIGHT	FSS 115	FSS 125	FSS 135	FSS 215	FSS 225	FSS 235	FSS 315	FSS 325	FSS 335	FSS 415	FSS 425	FSS 435
ROLLING	LESS THAN 150	FSC 116	FSC 126	FSC 136	FSC 216	FSC 226	FSC 236	FSC 316	FSC 326	FSC 336	-----	-----	-----
	BETWEEN 150 AND 300	FSC 117	FSC 127	FSC 137	FSC 217	FSC 227	FSC 237	FSC 317	FSC 327	FSC 337	-----	-----	-----
	BETWEEN 300 AND 450	FSC 118	FSC 128	FSC 138	FSC 218	FSC 228	FSC 238	FSC 318	FSC 328	FSC 338	-----	-----	-----
	MORE THAN 450	FSC 119	FSC 129	FSC 139	FSC 219	FSC 229	FSC 239	FSC 319	FSC 329	FSC 339	-----	-----	-----
	STRAIGHT	FSS 110	FSS 120	FSS 130	FSS 210	FSS 220	FSS 230	FSS 310	FSS 320	FSS 330	-----	-----	------

* Vehicle factors (make and model, maintenance condition etc).

* Human factors (driver behaviour etc).

3.2 Field Data Presentation

The requirement of the free speed study includes the effect of road width, road roughness and road curvature in plain terrain and rolling terrain. Taking all these parameters into consideration the framework that spells out the cells representing the road stretches with the specific road type, road roughness and radius of curvature where the free speed have been recorded for each of the vehicle types.

In order to assign a particular number to each of these cells a system of numbering was evolved by CRRI. Each of the site in a cell has been numbered as FSCxyz

FSC represents Free Speed on Curved sections.

x represents road width

1 for single lane

2 for intermediate lane

3 for two lane

y represents road roughness

1 for Rg less than 3000 mm/Km

2 for Rg between 3000 and 6000 mm/Km

3 for Rg more than 6000 mm/Km

z represents radius of curvature and terrain

1 and 6 for Rc less than 150m in plain terrain and rolling terrain respectively

2 and 7 for Rc between 150m and 300m in plain and rolling terrain respectively

3 and 8 for Rc between 300m and 450m in plain and rolling terrain respectively

4 and 9 for Rc more than 450m in plain terrain and rolling terrain respectively

5 and 0 for straight approach section in plain terrain and rolling terrain respectively.

3.3. Planning of the Study

The speed of only those vehicles are included which are being driven under free flow conditions and not influenced by either the road sight distance or because of the traffic conditions. Road stretches satisfying the requirements of each and every individual cell of the matrix framework as shown in the Table no.3.1 were identified.

Free speed of different types of vehicles were recorded with the help of radar speedmeters suitably located on the straight and curved sections of the selected road stretch with appropriate

road geometry.

Road geometry and the road roughness were measured for each individual site with the help of instruments like gyroscope, gradometer and car mounted bump integrator units etc by the Central Road Research Institute (CRRI).

The speed distribution thus obtained for various vehicle types in each cell of the above referred matrix was analyzed to test for the normal distribution through chi-square test as reported by the CRRI.

The median speed and the standard deviations as calculated for the observed set of data for each road type in plain or rolling terrain, horizontal curvature and road roughness are tabulated as per CRRI identifiers.

3.4 Free Vehicle Model of Indo-Swedish Traffic Simulation Model

The aim of the free vehicle model is to create a speed profile along the road for each free vehicle. This profile depends upon road geometry. The calculation is done in several steps according to the approach given below.

3.4.1 Roadwidth Model

According to this model, if the road width is <= 7m, median speed V_{1m} is obtained according to the following

expression, where speeds V_{Om} and V_{1m} are given in m/s.

$$\frac{1}{V_{1m}} = \frac{1}{V_{Om}} + \frac{a}{(v_b - 2.5\ )} - \frac{a}{2.5} \qquad (3.1)$$

where V_{Om} is the BDS in m/s

v_b is the road width in m

a is a calibration constant with a value of 0.0042 for all vehicle types.

Fig. 3.4.1 shows the median speed V_{1m} as a function of roadwidth for Ambassador car.

3.4.2 Model for Horizontal curve

If the road includes a horizontal curve, the median speed V_{1m} must be reduced taking into account the horizontal radius. Curves with a mean radius r>= 1000m do not affect speed V_{1m}. If V_{1m}<= 1000m the median speed V_{2m} on the curve is obtained with the following expression, where speeds V_{2m} and V_{1m} are given in m/s.

$$V_{2m} = \frac{1}{\mathrm{SQRT}((\frac{1}{V_{1m}})^2 + b\ ((\frac{1}{r}) - 0.001))} \qquad (3.2)$$

where r is the mean radius in meters

b is a calibration constant

Fig.3.4.2(a) to Fig. 3.4.2(c) shows median speed V_{2m} as a

function of curve radius r.

3.4.3 Surface Roughness Model

For a given roughness Rg, the median speed V_{3m} is obtained with the following expression where V_{3m} and V_{2m} are speeds in m/s

$$V_{3m} = V_{2m} * (e^{-c*Rg}) \tag{3.3}$$

where c is the calibration constant

Rg is the surface roughness in mm/km.

Fig.3.4.3(a) to Fig.3.4.3(d) shows the median speed V_{3m} as a function of free speed V_{2m} and surface roughness Rg.

Since the free vehicle model of Indo-Swedish Traffic Simulation Model considers only four vehicle types and has the same basic desired speed distribution for all the vehicle types, the number of parameters to be calibrated for free speed prediction are vary few. But considering the heterogeneity of the Indian road traffic, it is desired to assign separate basic desired speed distribution for each vehicle type. Thus the number of parameters that need to be calibrated is quite large. Moreover it is observed that, free vehicle model slightly over estimates the free speed when applies to Indian traffic conditions. Hence it has been decided to derive a polynomial fit for free speed prediction instead of free vehicle model, which gives more

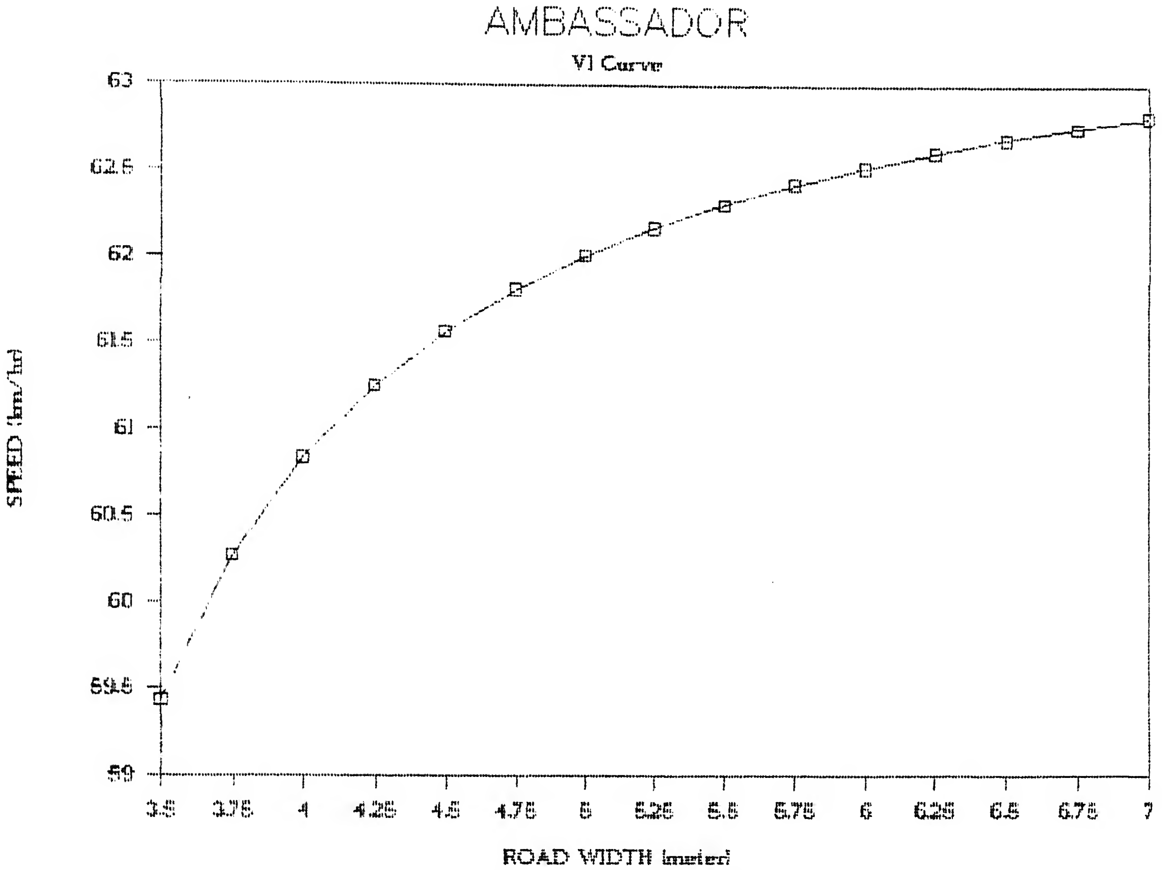


Fig. 3.4.1

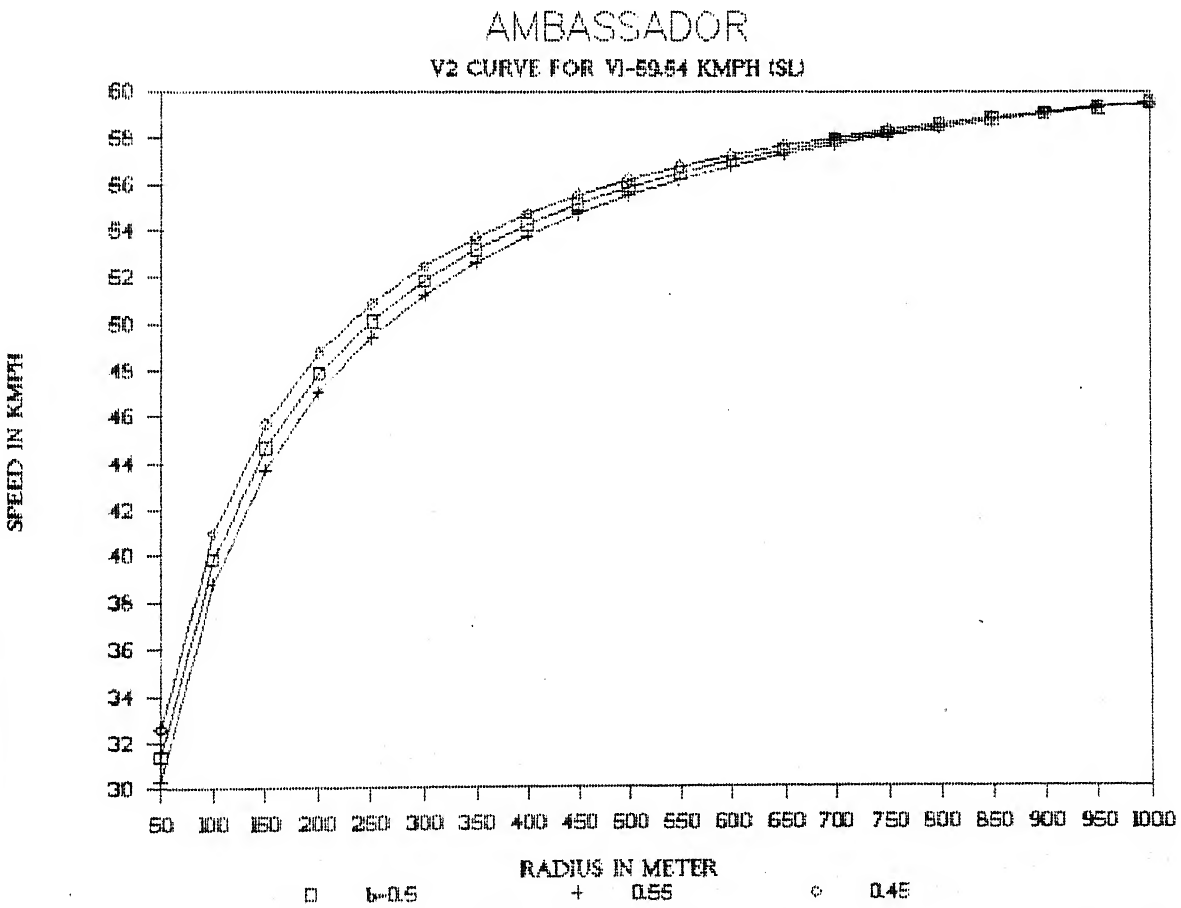


Fig. 3.4.2(a)

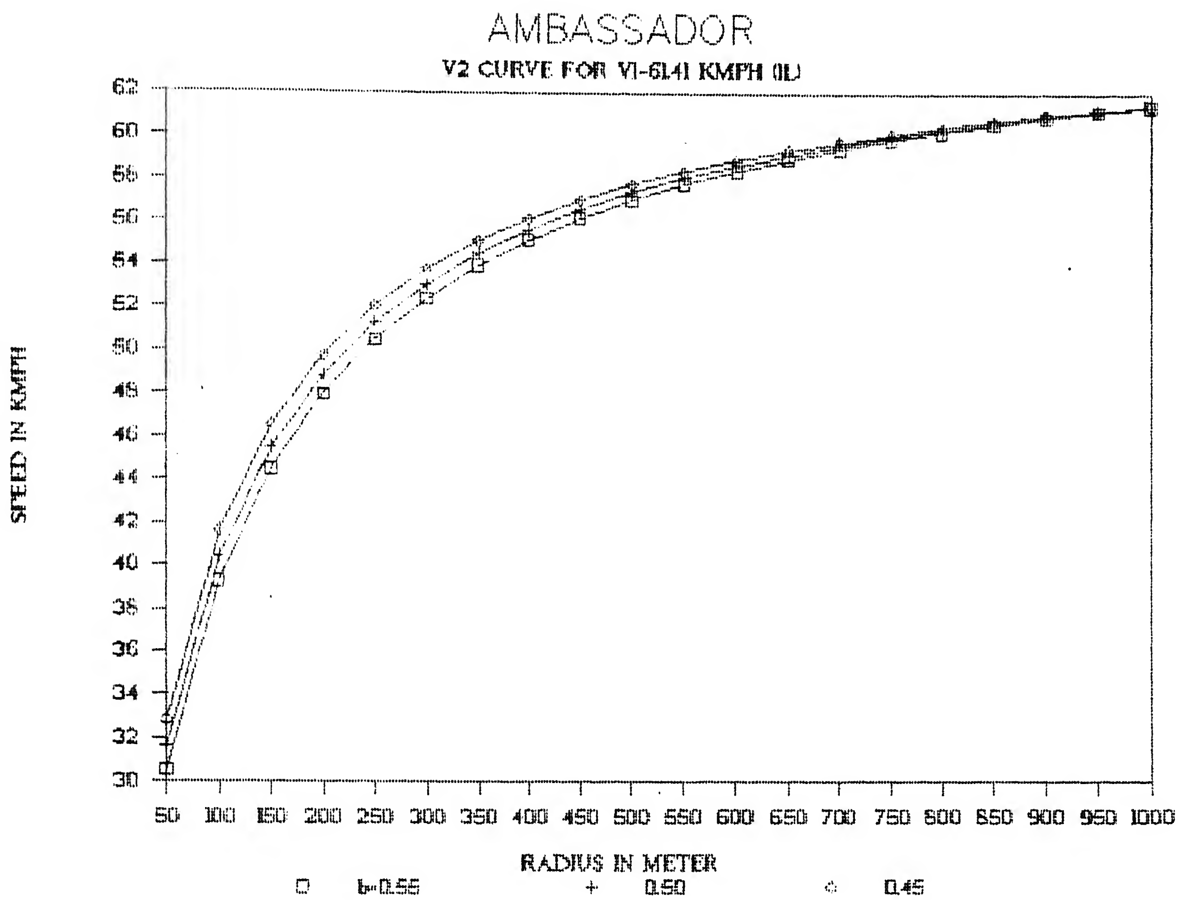


Fig 3.4.2(b)

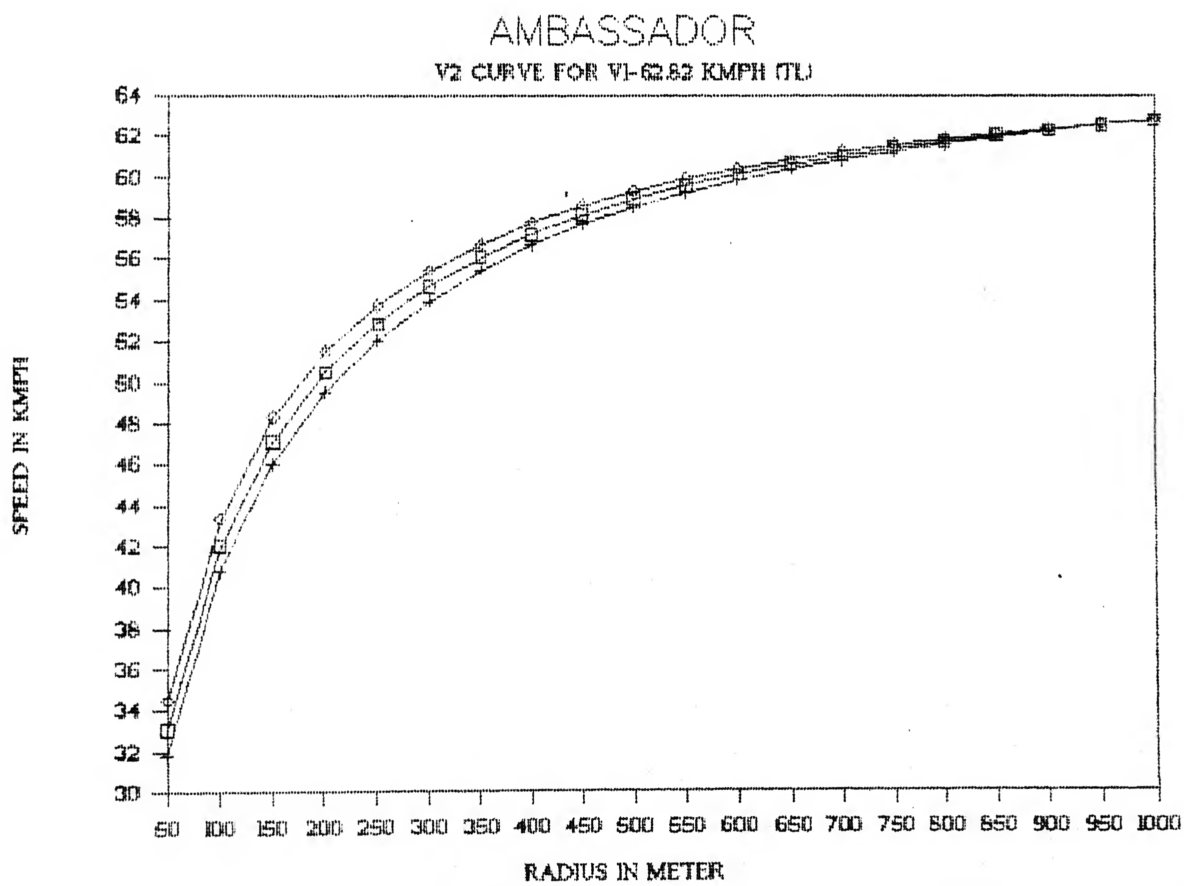


Fig. 3.4.2(c)

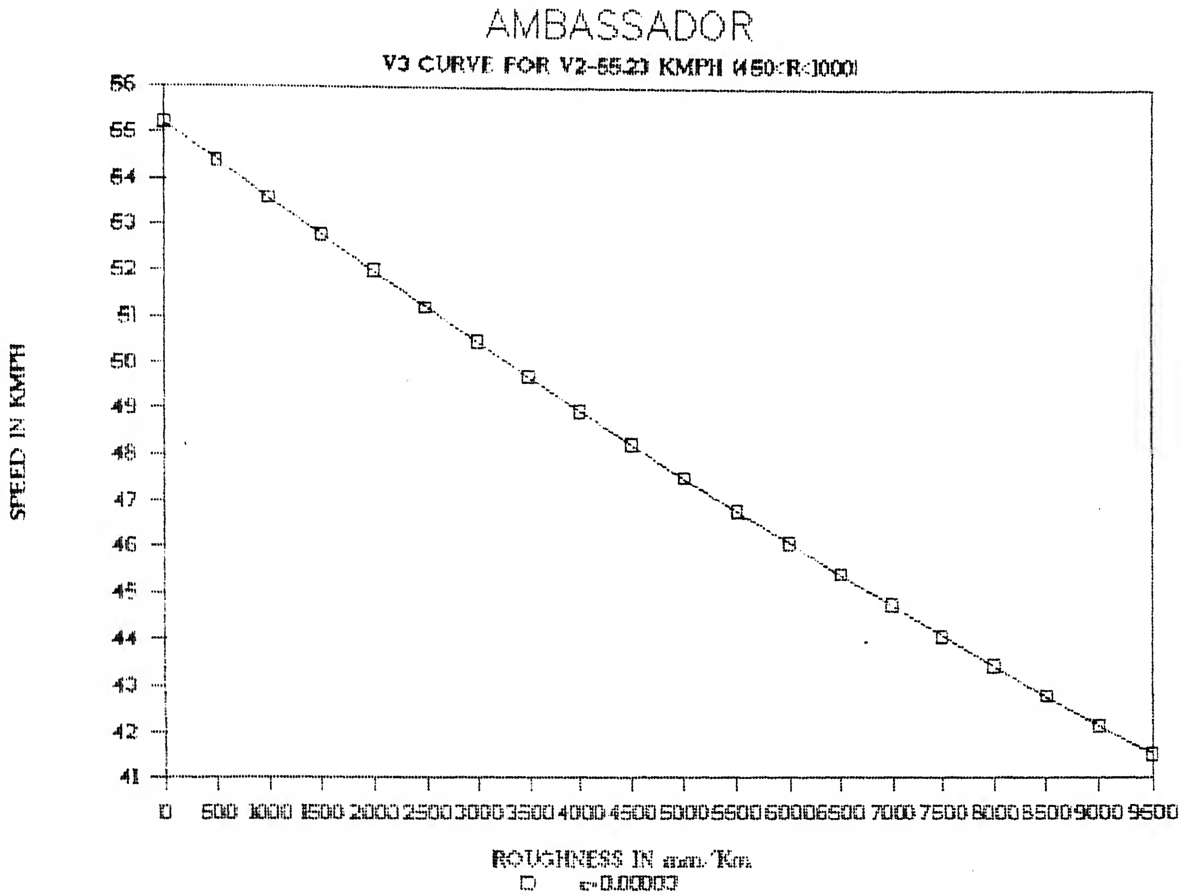


Fig. 3.4.3 (a)

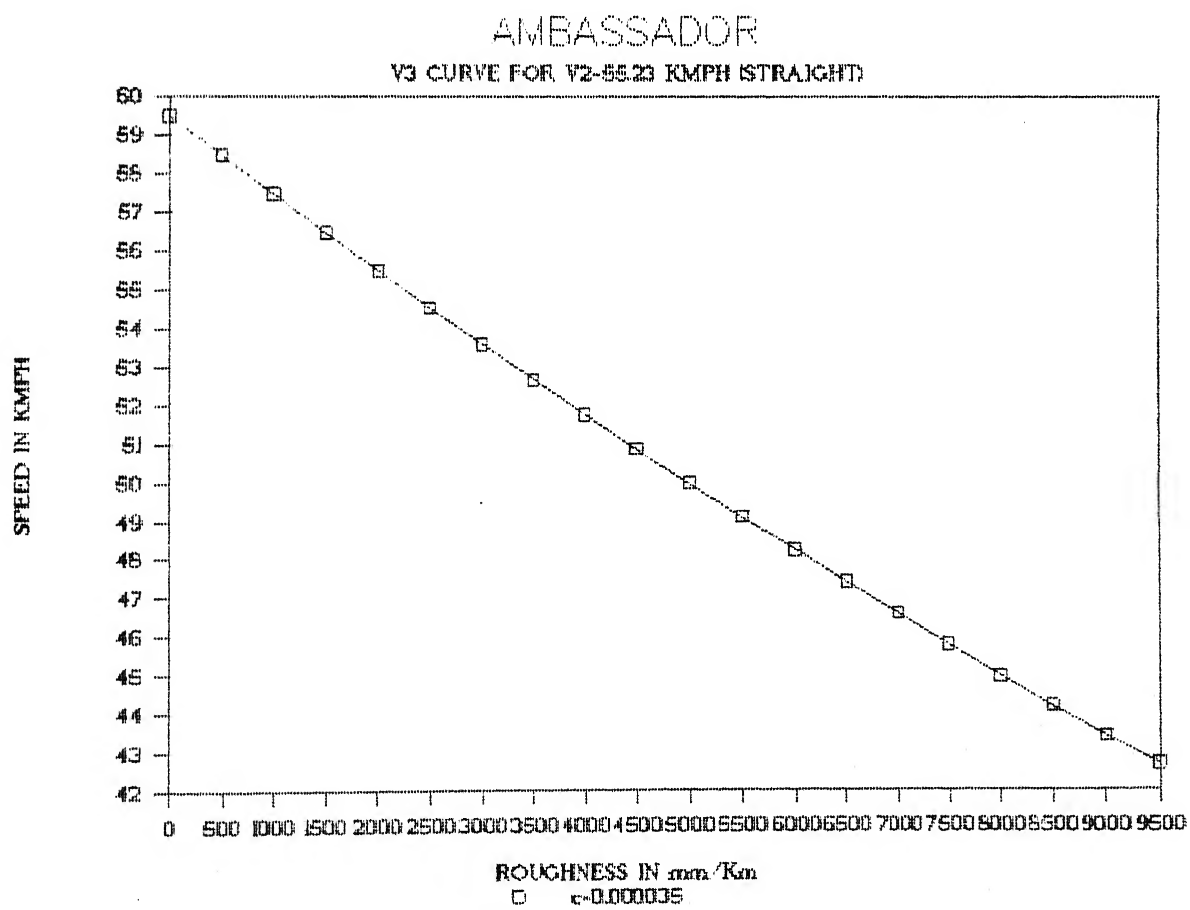


Fig. 3.4.3 (b)

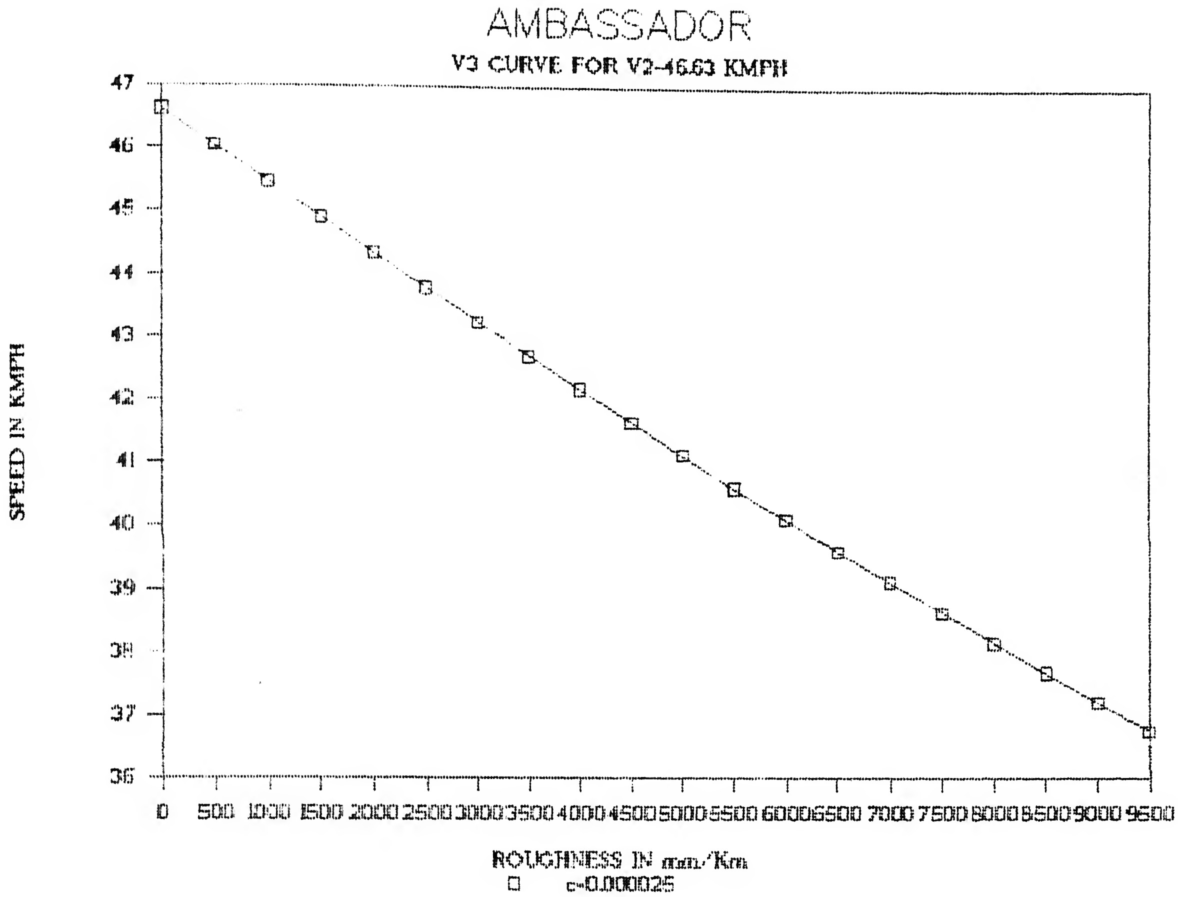


Fig. 3. 4. 3(c)

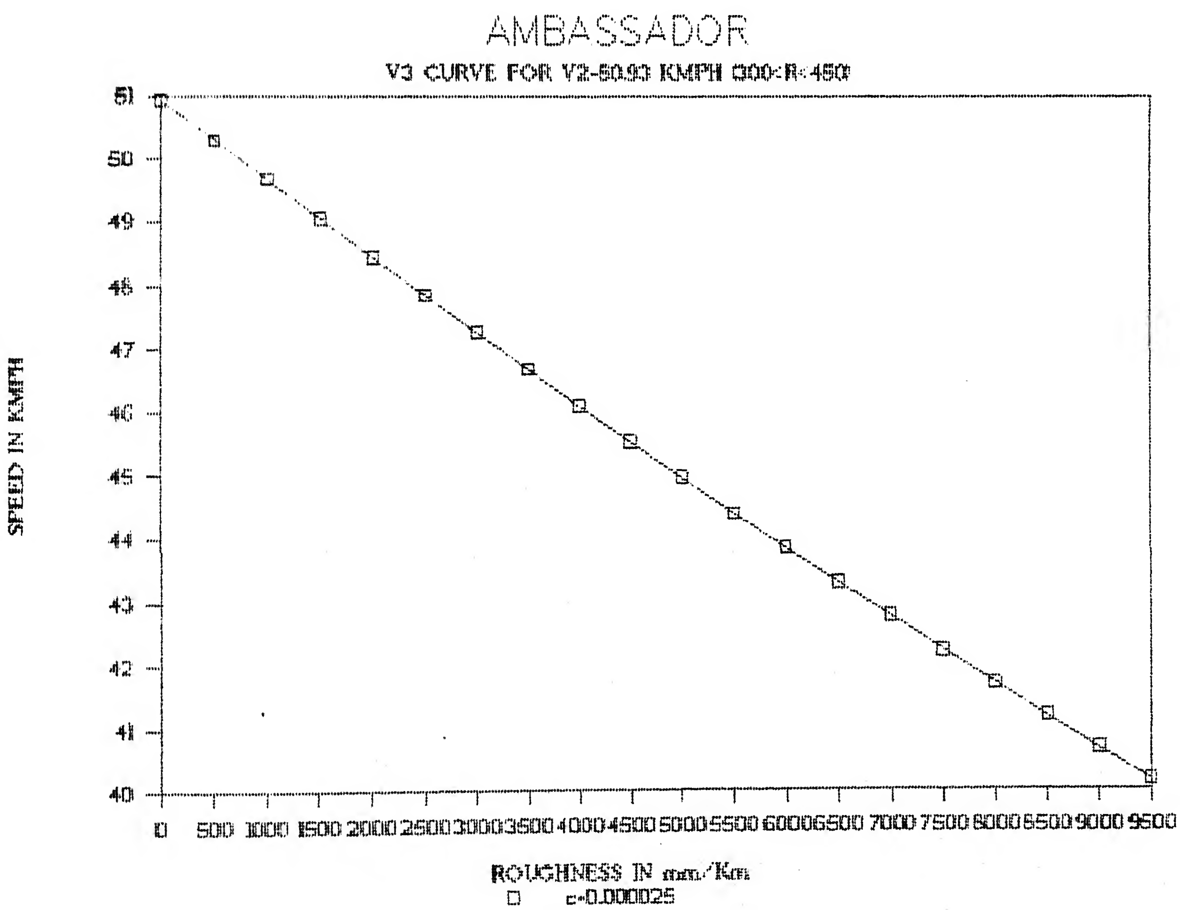


Fig. 3. 4. 3(d)

accurate prediction. The various steps involved in polynomial fit for free speed prediction has been explained in the subsequent sections below.

3.5 Polynomials for Free Speed Prediction

In order to predict the free speed for each and every cell in the above mentioned matrix framework, which is latter used in the main simulation program, number of polynomials are formulated using the observed data. The polynomials formulated for different road geometry are as follows:

1. Polynomial fit for roadwidth (V_1). (order =2)
2. Polynomial fit for curvature (V_2):

   This has three different polynomials

   (a) For single lane (SL) road . (Order=2)

   (b) For intermediate lane road (IL) (order=3)

   (C) For two lane road (TL) (Order=3)
3. Polynomial fit for roughness (V_3):

   This has following different types of polynomial:

   (a) For single lane road:

      i. For curvature <= 300m (order=2)

      ii. For 300m <curvature<= 450m (order=2)

      iii. For 450m <curvature<=1000m (order=2)

      iv. For straight road (order=2)

(b) For intermediate lane road:

i. For curvature <=150m (order=2)

ii. For 150m <curvature<=300m (order=2)

iii. For 300m <curvature<=450m (order=2)

iv. For 450m <curvature<=1000m (order=2)

v. For straight road (order=2)

(c) For two lane road:

i. For curvature<=150m (order=2)

ii. for 150m <curvature<=300m (order=2)

iii. For 300m <curvature<=450m (order=2)

iv. For 450m <curvature<=1000m (order=2)

v. For straight road(order=2)

3.5.1 Polynomial for Roadwidth

The form of the polynomial that have been fitted here is as follows

$$Y = a_0 + a_1.X + a_2.X^2$$

where Y= Free speed (V_1) of a particular vehicle.

X= Road width in meters.

a_0, a_1, a_2 are coefficients of the polynomial.

Since the order of the polynomial is two, three sets of equations are required to compute the value of the

computation of coefficients are

$$Y_1 = a_0 + a_1.X_1 + a_2.X_1^2$$

$$Y_2 = a_0 + a_1.X_2 + a_2.X_2^2$$

$$Y_3 = a_0 + a_1.X_3 + a_3.X_3^2$$

Where Y_1, Y_2, Y_3 are the free speed of a vehicle on single lane, intermediate lane and two lane roads respectively with minimum surface roughness on a tangent alignment (i,e straight road). The corresponding cell numbers are FSS 115, FSS 215, and FSS315. X_1, X_2, and X_3 = Roadwidth corresponding to single lane, intermediate lane and two lane roads respectively (i.e.3.5m, 5.5m and 7.0m).The computed coefficients for different vehicles are shown in the Table 3.5.1.

3.5.2 Polynomial for Radius of Curvature

In order to predict the free speed of a vehicle on a curved segment of a road of radius of curvature X meter for a particular road width a polynomial of the form

$$Y = a_0 + a_1.X + a_2.X^2 \quad \text{for single lane road}$$

$$Y = a_0 + a_1.X + a_2.X^2 + a_3.X^3 \quad \text{for two and three lane road.}$$

were formulated. Here Y indicates free speed of a vehicle on a curved road of radius of curvature X meter. In order to compute the coefficients of the polynomial three sets of equations for

single lane and four sets of equations for intermediate and two lane roads are solved. The set of equations that are solved for single lane are:

$$Y_1 = a_0 + a_1.X_1 + a_2.X_1^2$$
$$Y_2 = a_0 + a_1.X_2 + a_2.X_2^2$$
$$Y_3 = a_0 + a_1.X_3 + a_2.X_3^2$$

Where Y_1, Y_2, Y_3 are the speeds corresponding to the cell number FSC 112, FSC 113, FSC 114 respectively. X_1, X_2, X_3 are the radius of curvature 150m, 375m, and 725m respectively. Since observations have been made in three different groups of horizontal curve (less than 300m, between 300m and 450m, and 450m and 100m) the mid values of each group has been taken.

For intermediate lane and two lane roads the sets of equations that are solved for computing the coefficients are

$$Y_1 = a_0 + a_1.X_1 + a_2.X_1^2 + a_3.X_1^3$$
$$Y_2 = a_0 + a_1.X_2 + a_2.X_2^2 + a_3.X_2^3$$
$$Y_3 = a_0 + a_1.X_3 + a_2.X_3^2 + a_3.X_3^3$$
$$Y_4 = a_0 + a_1.X_4 + a_2.X_4^2 + a_3.X_4^3$$

Where Y_1, Y_2, Y_3, Y_4 are speeds corresponding to the cell number FSC 211, FSC 212, FSC 213, FSC 214 respectively for intermediate lane and FSC 311, FSC 312, FSC 313, FSC 314 respectively for two lane road. The values of X_1, X_2, X_3 and X_4 taken are 75m, 225m, 375m and 725m respectively(i.e. mid values of less than 150m, 150m to 300m, 300m to 450m, and 450m to 1000m). The

3.5.3 Polynomial for Surface Roughness

In order to predict the free speed of a vehicle for any given roughness, curvature and roadwidth, a polynomial of the form

$$Y= a_0 + a_1.X + a_2.X^2$$

is formulated. Here Y represents free speed of a vehicle for a given roadwidth, radius of curvature and of roughness X mm/Km. a_0, a_1, a_2 are the coefficients of the polynomial. In order to compute the coefficients of the polynomial, three sets of equations for a given roadwidth and radius of curvature are solved. The equations that are solved are as follows

$$Y_1= a_0+ a_1.X_1+ a_2.X_1^2$$

$$Y_2= a_0+ a_1.X_2+ a_2.X_2^2$$

$$Y_3= a_0+ a_1.X_3+ a_3.X_3^2$$

Where Y_1,Y_2,Y_3 are the speed corresponding to the cell number FSS 115,FSS 125, FSS 135 for single lane straight road. And X_1,X_2,X_3 are the values of surface roughness 1500 mm/Km, 4500 mm/Km and 7500 mm/Km respectively(i.e. mid values of less than 3000 mm/km, between 3000 mm/km and 6000 mm/km, and more than 6000 mm/km). The computed values of the coefficients are shown in the Table 3.5.3.

The predictions have been made with the polynomials as derived above, and the predicted values were found to be very close to the actual values. The polynomials were subsequently implemented in the road submodel, and the results obtained by the

explains the different steps involved in calibration of Q Value for different vehicle types.

TABLE 3.5.1 COEFFICIENTS OF THE POLYNOMIAL FOR ROAD WIDTH EFFECT

VEH. TYPE	a_0	a_1	a_2
AMBASSADOR	56.24	0.94	-9.50×10^{-7}
FIAT	59.12	1.02	-1.42×10^{-3}
MARUTI	63.99	1.28	-1.43×10^{-3}
JEEP	51.77	0.84	-9.53×10^{-4}
SCOOTER	45.95	0.72	-1.90×10^{-3}
MATADOR	50.46	0.69	-9.53×10^{-4}
BUS	58.98	0.76	9.51×10^{-4}
LCV	50.95	0.66	1.42×10^{-3}
TRUCK	54.72	0.82	-1.42×10^{-3}
TRACTOR	25.87	0.32	-4.76×10^{-4}

TABLE 3.5.3(a) COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE :AMBASSADOR

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	67.31	-2.59×10^{-3}	0.00	68.34	-2.31×10^{-3}	0.00	68.96	-2.04×10^{-3}	-5.55×10^{-10}
600m.	60.76	-1.70×10^{-3}	-4.61×10^{-8}	61.36	-1.29×10^{-3}	-6.38×10^{-8}	63.27	-1.20×10^{-3}	-6.33×10^{-8}
450m.	54.24	-8.29×10^{-4}	-9.11×10^{-8}	54.38	-2.73×10^{-4}	-1.27×10^{-7}	57.52	-3.39×10^{-4}	-1.28×10^{-7}
300m.	47.69	5.83×10^{-5}	-1.30×10^{-7}	47.46	7.23×10^{-4}	-1.90×10^{-7}	51.76	5.28×10^{-4}	-1.92×10^{-7}
150m.	---	---	---	47.64	1.63×10^{-4}	-1.27×10^{-7}	52.10	-3.53×10^{-4}	-9.2×10^{-8}

COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE :FIAT

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	70.58	-2.64×10^{-3}	-2.27×10^{-13}	72.35	-2.56×10^{-3}	-5.55×10^{-10}	73.00	-2.27×10^{-3}	-4.54×10^{-13}
600m.	63.21	-1.63×10^{-3}	-5.67×10^{-8}	64.12	-1.12×10^{-3}	-9.49×10^{-8}	66.77	-1.33×10^{-3}	-7.11×10^{-8}
450m.	55.85	-6.36×10^{-4}	-1.12×10^{-7}	55.85	3.27×10^{-4}	-1.91×10^{-7}	60.55	-3.93×10^{-4}	-1.41×10^{-7}
300m.	48.46	3.73×10^{-4}	-1.69×10^{-7}	47.65	1.75×10^{-3}	-2.12×10^{-7}	54.35	5.40×10^{-4}	-2.11×10^{-7}
150m.	---	---	---	47.74	1.10×10^{-3}	-2.12×10^{-7}	53.23	1.67×10^{-6}	-1.27×10^{-7}

TABLE 3.5.3(b) COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : MARUTI

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	75.38	-2.30×10^{-3}	-5.55×10^{-10}	77.80	-2.27×10^{-3}	-4.54×10^{-13}	78.95	-2.02×10^{-3}	4.55×10^{-13}
600m.	69.46	-1.74×10^{-3}	-4.27×10^{-8}	70.44	-1.05×10^{-3}	-9.89×10^{-8}	74.66	-1.71×10^{-3}	-3.38×10^{-8}
450m.	63.51	-1.16×10^{-3}	-8.61×10^{-8}	63.05	1.80×10^{-4}	-1.98×10^{-7}	70.40	-1.41×10^{-3}	-6.67×10^{-8}
300m.	57.56	-5.81×10^{-4}	-1.29×10^{-7}	55.66	1.41×10^{-3}	-2.98×10^{-7}	66.11	-1.09×10^{-3}	-1.00×10^{-7}
150m.	---	---	---	56.57	6.03×10^{-4}	-2.11×10^{-7}	68.39	-2.59×10^{-3}	-4.17×10^{-8}

COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : JEEP

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	60.38	-1.89×10^{-3}	0.00	63.25	-2.30×10^{-3}	-2.27×10^{-13}	63.33	-1.90×10^{-3}	0.00
600m.	53.87	-9.27×10^{-4}	-6.66×10^{-8}	56.76	-1.21×10^{-3}	-7.05×10^{-8}	56.79	-5.85×10^{-4}	-1.05×10^{-7}
450m.	47.37	3.83×10^{-5}	-1.32×10^{-7}	50.27	-1.23×10^{-4}	-1.41×10^{-7}	50.24	7.46×10^{-4}	-2.11×10^{-7}
300m.	40.86	1.00×10^{-3}	-1.99×10^{-7}	43.76	9.73×10^{-4}	-2.12×10^{-7}	43.73	2.07×10^{-3}	-3.16×10^{-7}
150m.	---	---	---	44,86	-1.66×10^{-6}	-1.11×10^{-7}	43..68	1.34×10^{-3}	-2.27×10^{-7}

TABLE 3.5.3(c) COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : SCOOTER

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	53.21	-1.59×10^{-3}	2.27×10^{-13}	53.85	-1.33×10^{-3}	5.55×10^{-10}	54.78	-1.30×10^{-3}	2.27×10^{-13}
600m.	51.15	-1.49×10^{-3}	-1.72×10^{-8}	50.22	-7.68×10^{-4}	-5.61×10^{-8}	50.78	-3.52×10^{-4}	-9.05×10^{-8}
450m.	49.13	-1.40×10^{-3}	-3.27×10^{-8}	56.62	-2.12×10^{-4}	-1.12×10^{-7}	46.73	0.13×10^{-4}	-1.82×10^{-7}
300m.	47.08	-1.31×10^{-3}	-4.94×10^{-8}	43.02	3.44×10^{-4}	-1.67×10^{-7}	42.74	1.55×10^{-3}	-2.72×10^{-7}
150m.	---	---	---	42.11	-1.41×10^{-4}	-9.39×10^{-8}	41.48	8.70×10^{-4}	-1.68×10^{-7}

COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : MATADOR

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	59.78	-2.29×10^{-3}	0.00	60.71	-2.14×10^{-3}	-2.27×10^{-13}	60.88	-1.86×10^{-3}	5.55×10^{-10}
600m.	53.26	-1.33×10^{-3}	-5.55×10^{-8}	53.98	-9.41×10^{-4}	-8.05×10^{-8}	55.62	-1.02×10^{-3}	-6.38×10^{-8}
450m.	46.73	-3.70×10^{-4}	-1.11×10^{-7}	47.25	2.58×10^{-4}	-1.60×10^{-7}	50.37	-1.73×10^{-4}	-1.27×10^{-7}
300m.	40.18	6.02×10^{-4}	-1.67×10^{-7}	40.52	1.45×10^{-3}	-2.40×10^{-7}	45.12	6.73×10^{-4}	-1.92×10^{-7}
150m.	---	---	---	40.69	7.49×10^{-4}	-1.58×10^{-7}	44.83	9.33×10^{-5}	-1.18×10^{-7}

TABLE 3.5.3(d) COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE :BUS

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	67.72	-2.02×10^{-3}	2.27×10^{-13}	68.23	-1.67×10^{-3}	5.54×10^{-10}	68.19	-1.27×10^{-3}	-5.55×10^{-10}
600m.	61.85	-1.40×10^{-3}	-5.00×10^{-8}	61.90	-8.75×10^{-4}	-7.39×10^{-8}	62.18	-2.38×10^{-4}	-1.12×10^{-7}
450m.	55.98	-7.86×10^{-4}	-1.00×10^{-7}	55.61	-8.49×10^{-5}	-1.47×10^{-7}	56.09	8.11×10^{-4}	-2.26×10^{-7}
300m.	50.14	-1.78×10^{-4}	-1.49×10^{-7}	49.31	7.05×10^{-4}	-2.20×10^{-7}	50.02	1.87×10^{-3}	-3.40×10^{-7}
150m.	---	---	---	50.37	-2.91×10^{-4}	-9.49×10^{-8}	48.71	1.33×10^{-3}	-2.36×10^{-7}

COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : LCV

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	58.71	-1.81×10^{-3}	-5.55×10^{-10}	60.07	-1.81×10^{-3}	-5.56×10^{-10}	59.90	-1.41×10^{-3}	2.27×10^{-13}
600m.	52.18	-7.66×10^{-4}	-7.78×10^{-8}	54.42	-9.50×10^{-4}	-6.67×10^{-8}	54.23	-3.07×10^{-4}	-1.02×10^{-7}
450m.	45.63	2.79×10^{-4}	-1.56×10^{-7}	48.74	-8.33×10^{-5}	-1.33×10^{-7}	48.52	8.18×10^{-4}	-2.06×10^{-7}
300m.	39.07	1.32×10^{-3}	-2.33×10^{-7}	43.08	7.80×10^{-4}	-2.00×10^{-7}	42.84	1.93×10^{-3}	-3.09×10^{7}
150m.	---	---	---	43.93	-1.34×10^{-4}	-9.50×10^{-8}	42.16	1.43×10^{-3}	-2.29×10^{-7}

TABLE 3.5.3(e) COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE :TRUCK

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	65.40	-2.61×10^{-3}	-4.54×10^{-13}	67.02	-2.61×10^{-3}	-2.27×10^{-13}	67.59	-2.40×10^{-3}	0.000
600m.	55.78	-1.12×10^{-3}	-8.39×10^{-8}	58.43	-1.35×10^{-3}	-6.94×10^{-8}	60.21	-1.31×10^{-3}	-6.83×10^{-8}
450m.	45.95	4.60×10^{-4}	-1.75×10^{-7}	49.84	-1.03×10^{-4}	-1.38×10^{-7}	52.83	-2.13×10^{-4}	-1.37×10^{-7}
300m.	36.19	2.00×10^{-3}	-2.64×10^{-7}	41.28	1.14×10^{-3}	-2.07×10^{-7}	45.43	8.84×10^{-4}	-2.05×10^{-7}
150m.	---	---	---	43.32	3.05×10^{-4}	-1.32×10^{-7}	46.98	-8.83×10^{-5}	-1.05×10^{-7}

COEFFICIENTS OF THE POLYNOMIAL FOR ROUGHNESS EFFECT

VEH. TYPE : TRACTOR

RADIUS OF CURVATURE	SINGLE LANE a_0	SINGLE LANE a_1	SINGLE LANE a_2	INTERMEDIATE LANE a_0	INTERMEDIATE LANE a_1	INTERMEDIATE LANE a_2	TWO LANE a_0	TWO LANE a_1	TWO LANE a_2
STRAIGHT	29.71	-9.10×10^{-4}	-1.13×10^{-13}	30.30	-8.97×10^{-4}	-1.13×10^{-13}	30.59	-8.35×10^{-4}	-5.55×10^{-10}
600m.	27.64	-8.07×10^{-4}	-2.22×10^{-9}	26.97	-2.52×10^{-4}	-4.94×10^{-8}	28.11	-3.48×10^{-4}	-4.27×10^{-8}
450m.	25.57	-6.98×10^{-4}	-5.00×10^{-9}	23.71	3.67×10^{-4}	-9.67×10^{-8}	25.63	1.38×10^{-4}	-8.49×10^{-8}
300m.	23.47	-5.82×10^{-4}	-8.33×10^{-9}	20.41	1.00×10^{-3}	-1.45×10^{-7}	23.15	6.25×10^{-4}	-1.27×10^{-7}
150m.	---	---	---	19.02	1.15×10^{-3}	-1.37×10^{-7}	22.33	4.92×10^{-4}	-9.83×10^{-8}

CHAPTER IV

FREE SPEED MODELING

4.1 General

Free speed (FS) of a vehicle is the speed it can actually maintain on a road stretch in the absence of any traffic interaction. In case of ideal road condition FS equals BDS (V_0). However, if road geometry, including surface characteristics imposes any restrictions, FS would be lower than the BDS, the extent of reduction depending upon the type and magnitude of the constraints.

The main road factors influencing travel speed, resulting in FS value lower than BDS are identified as:

1. Road width
2. Horizontal curvature
3. Surface roughness

4.2 Model for Transformation of Basic Desired Speed Distribution

We know that basic desired speed V_{0m} is reduced to median speed V_{3m} when influenced by road width, horizontal curvature and surface roughness.

It is now necessary to create a distribution of the speed about the median value V_{3m}, termed asthe desired speed

termed as Q value.

4.2.1 Importance of Q-Value in Simulation Program

In the main simulation program for each road block and for each vehicle free block speed is calculated using the following equation.

$$\text{freeblock speed} = (VON^{Q} + DVQ)^{1/Q}$$

Where VON is the basic desired speed. This basic desired speed for a vehicle is obtained from the BDS distribution of the vehicle from the traffic file.

$$DVQ = V_{3m}^{Q} - VOM^{Q}$$

VOM = Median basic desired speed distribution.

V_{3m} = Median block speed which is obtained after considering the roadwidth, horizontal curvature and pavement surface roughness.

Q is the measure of rotation which shows how far the free speed distribution is shifted because of the roadwidth, curvature and pavement surface roughness.

4.2.2 Importance of Q-Value in Traffic Generation

The same Q value is used for determining the basic desired speed of the vehicle in traffic generation programme for the field traffic data. The procedure used for calculating the BDS for the field traffic is as follows.

The basic desired speed of the vehicle from the given BDS distribution is given by

$$BDS = v(j,i)^{Q} + DVQ(j,i)^{1/Q}$$

Where $v(j,i)$ is the basic desired speed of the i th type vehicle at j th percentage. Percentage 'j' is drawn randomly from the inbuilt procedure.

Q is the rotation factor for i th vehicle.

$DVQ(j,i)$ is calculated by using the equation

$$DVQ(j,i) = V_{Om}^{\ Q} - V3M^{\ Q}$$

where V_{Om} is the median basic desired speed and V3M is the observed median speed at the site.

Hence the value of Q is an important factor in determining the free block speed for each vehicle in the simulation program and in determining the BDS from

the spot speed in traffic generation program from the field data.

4.2.3 Determination of Q-Value

The Q value is a function of the median speeds V_{0m}, V_{1m}, V_{2m}, and V_{3m}. Using the free speed distribution V_3, the Q value is determined as follows.

$$V_{0i}^{Q} - V_{3i}^{Q} = V_{0m}^{Q} - V_{3m}^{Q}$$

Where V_{0i} and V_{3i} are speeds at an arbitrary percentile in basic desired speed and free speed distributions respectively.

If Q = 1 then the above equation results in a purely parallel shift indicating a constant reduction in speed for fast moving as well as slow moving vehicles as shown in the Fig.4.2.1

However, when Q < 1 thefree speed distribution, V_3, is rotated in anticlockwise direction showing that a driver with a higher BDS reduces his speed more than a driver with a lower BDS when influenced by speed reducing factors as shown in the Fig.4.2.2 . It must be noted that the smaller the value of Q, the larger will be the rotation. Each roadway factor namely the roadwidth, horizontal curvature and pavement surface roughness has its own isolated measure of

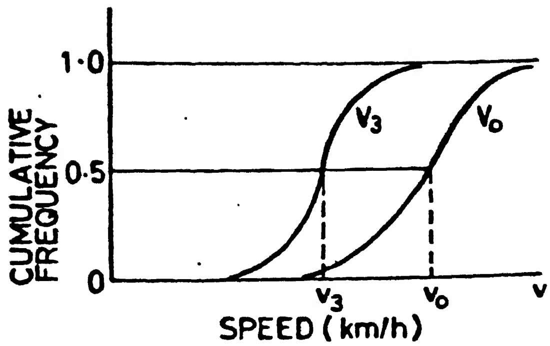


Fig. 4.2.2 Effect of Road Geometry on BDS

Distribution V_O

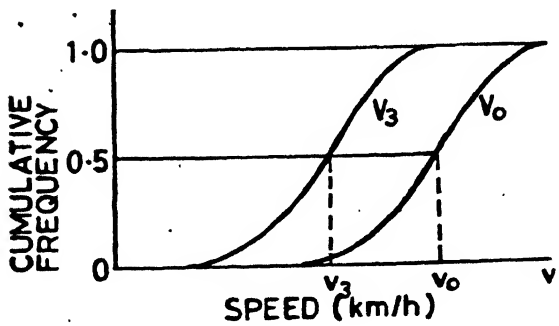


Fig. 4.2.1 Effect of Road Geometry on BDS Distribution

Uniform reduction at high as well as low speed

4.2.4 Determination of q_i Values:

A calibration constant $q_i \leq 1$ such that $V_i^{q_i}$ is approximately distributed as $V_o^{q_i}$ minus a shift, d_i, which is dependent only on the factor i. Thus q_i describes the effect of the factor i on the shape of V_o. i.e. $V_i^{q_i} = V_o^{q_i} + d.$

Hence for every sample v_i from V_i, v_o from V_o

$$v_i^{q_i} = v_o^{q_i} + d$$

Differentiating: $$q_i \, v_i^{q_i - 1} \, dv_i = q_i \, v_o^{q_i - 1} \, dv_o$$

$$\left[\frac{v_o}{v_i} \right]^{1-q_i} = \left[\frac{dv_o}{dv_i} \right]$$

$$1 - q_i = \frac{\log \left[\dfrac{dv_o}{dv_i} \right]}{\log \left[\dfrac{v_o}{v_i} \right]} = \text{constant}$$

From the above equation q_i value can be obtained. In the case of VTI model these constants were calibrated for the Swedish road and traffic conditions and they are:

q_i = 0.5 for road width.

q_2 = -0.8 for horizontal curve.

q_3 = -2.0 for speed limit.

These values were used for all the vehicle types(i.e. four different types of vehicle) and they had adopted only one BDS for all vehicular traffic on Swedish roads.

In the VTI model these constants were calibrated without differentiating the roadwidth as they have mostly 7m or wider roads. But in the case of Indian roads roadwidth vary from 3.5m wide single lane roads to 7.0 m wide two lane roads.It is interesting to observe the rotations with respect to road width for each vehicle type. Hence the rotation factors for each vehicle type, on each type of roadwidth for the effect of road width, horizontal curve and surface roughness, q_{ij}, can be obtained. Where i = 1,2,3 (i.e. effect of roadwidth, radius of curve, surface roughness.), j = 1 to number of vehicle types. The approximate procedure for obtaining the q_{ij} is as follows.

1. Determine the BDS distribution with 2% increment in the cumulative distribution for each vehicle type.

2. Determine the free speed distribution at 3.5m, 5.5m, and 7.0m wide roads with the effect of roadwidth, horizontal curve, and roughness can be obtained with 2%

increment in the cumulative distribution for each vehicle type.

3. The value of q_{1j} at roadwidth w and for vehicle type j can be calculated as follows.

$$1 - q_{1j} = \frac{\log(dv_{oj} / dv_{1j})}{\log(v_{oj} / v_{1j})}$$

4. Similarly these distributions are to be calibrated at a particular horizontal curve on each of the road width class.(i.e. at 3.5m, 5.5m and 7.0m). From these distributions as mentioned above q_{2j} and q_{3j} are to be calculated.

The following example shows the determination of q_{ij} value for given distributions of V_{1j} and V_{oj}. Fig.4.2.3 shows the assumed distribution of V_{1j} and V_{oj}. Two tangents are drawn at 50 percentile on both the distributions as shown in the Fig.. The values of dv_{oj} ,dv_{1j}, v_{oj} and v_{1j} are measured as shown in the Figure. The value of q_{1j} is calculated using the above equation. Distributions of $V_{1j}^{q_{1j}}$, $V_{Oj}^{q_{1j}}$ were calculated using q_{1j} value. Fig.4.2.4 shows the variation of these distributions.

Vo and V1 Distributions

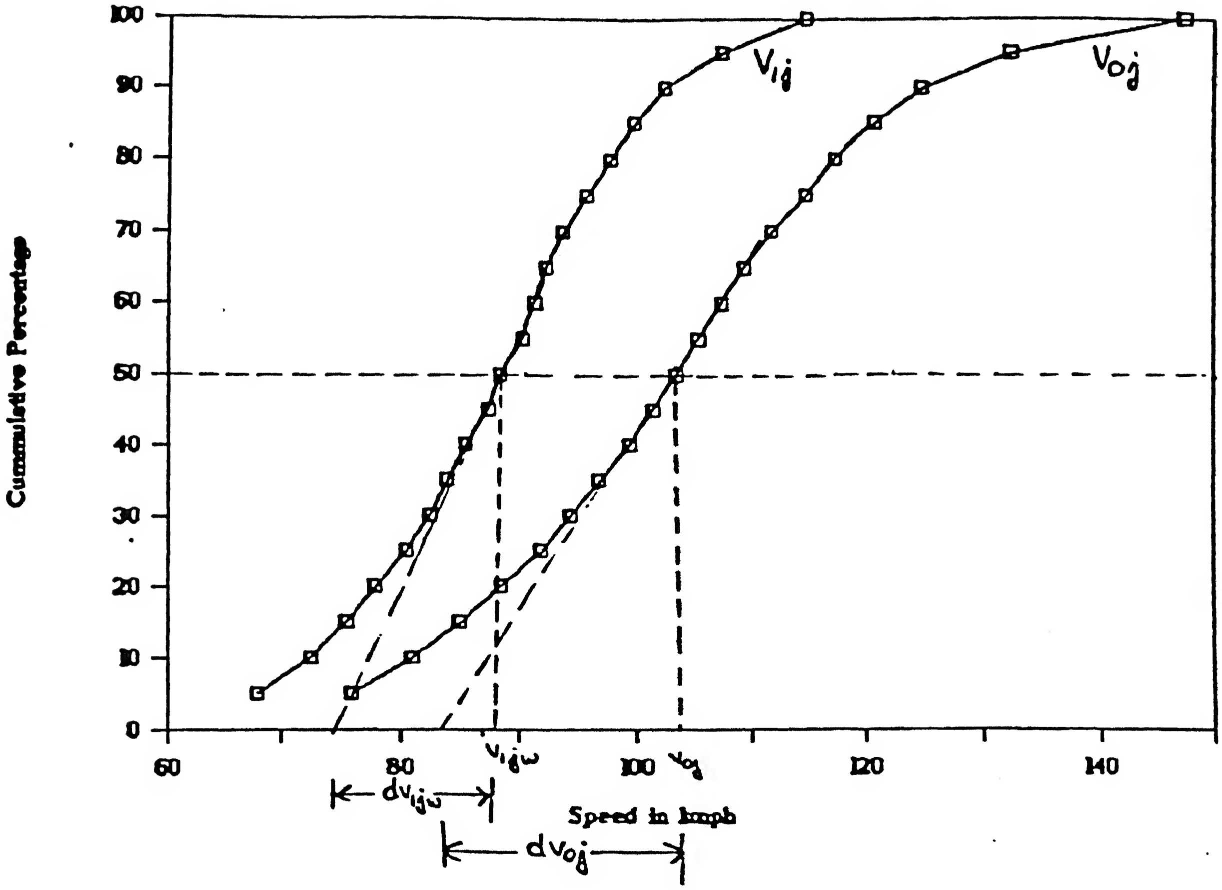


Fig. 4.2.3

4.2.4 . Diff between Vo^qi and V1^qi

qi--166

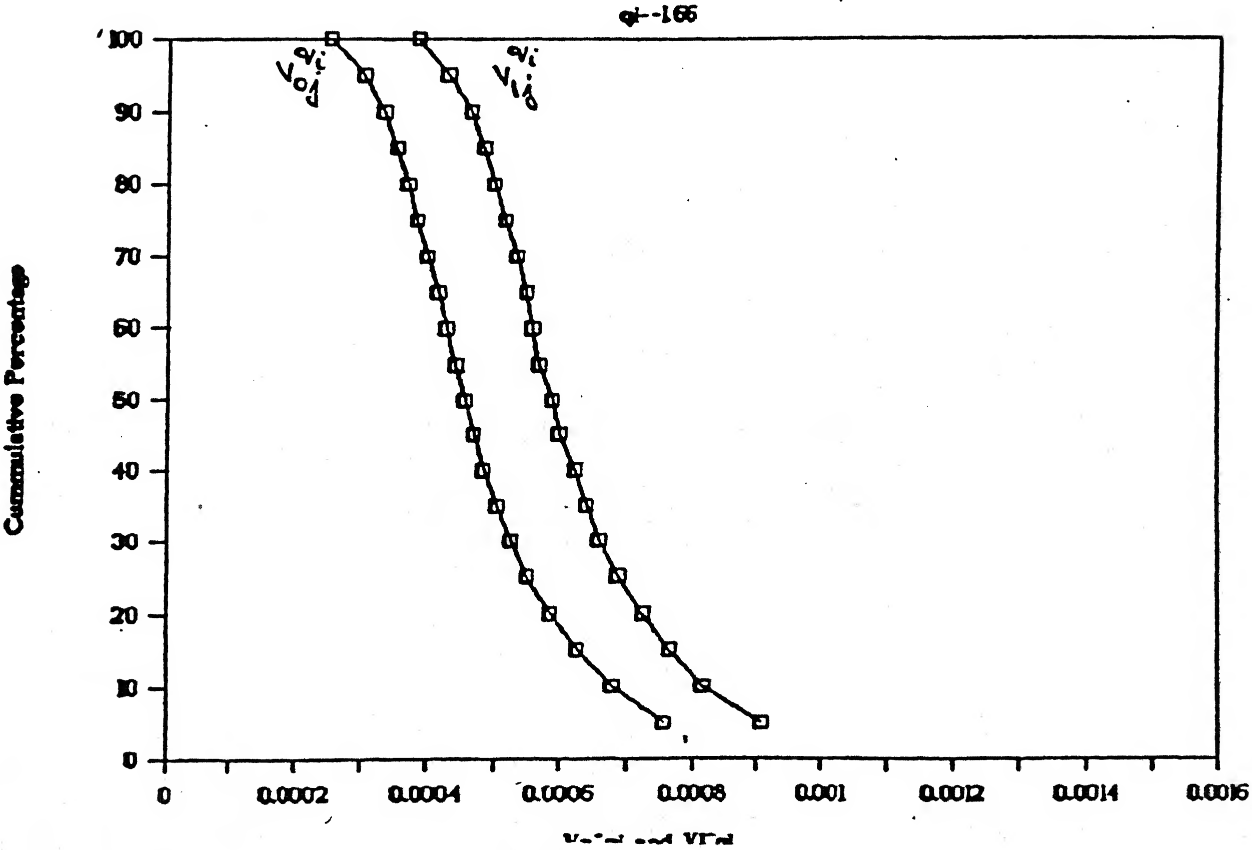


Fig. 4.2.4

Table 4.1 Values of V_{oj}, V_{1j}, $V_{oj}^{q_{1j}}$ and $V_{1j}^{q_{1j}}$ distributions:

Cumulative Percentage	V_{1j}	V_{oj}	$V_{1j}^{q_{1j}}$	$V_{oj}^{q_{1j}}$	$V_{oj}^{q_{1j}} - V_{1j}^{q_{1j}}$
5	68.0	76.0	0.000907	0.000754	-0.00015
10	72.5	81.0	0.000816	0.000679	-0.00013
15	75.5	85.0	0.000763	0.000626	-0.00013
20	78.0	88.5	0.000722	0.000586	-0.00013
25	80.5	92.0	0.000686	0.000549	-0.00013
30	82.5	94.5	0.000658	0.000525	-0.00013
35	84.0	97.0	0.000639	0.000503	-0.00013
40	85.5	99.5	0.000620	0.000482	-0.00013
45	87.5	101.5	0.000597	0.000466	-0.00013
50	88.5	103.5	0.000586	0.000452	-0.00013
55	90.5	105.5	0.000564	0.000437	-0.00012
60	91.5	107.5	0.000554	0.000424	-0.00013
65	92.5	109.5	0.000544	0.000411	-0.00013
70	94.0	112.0	0.000530	0.000396	-0.00013
75	96.0	115.0	0.000512	0.000379	-0.00013
80	98.0	117.5	0.000494	0.000366	-0.00012
85	100.0	121.0	0.000478	0.000348	-0.00012
90	102.5	125.0	0.000459	0.000330	-0.00012
95	107.5	132.5	0.000424	0.000300	-0.00012
100	115.0	147.5	0.000379	0.000251	-0.00012

equally spaced. Table 4.1 shows the values used for V_{1j}, V_{0j} distributions and $V_{0j}^{q_{1j}} - V_{1j}^{q_{1j}}$. From these values it can be concluded that the value of q_{1j} describes parallel shift between V_{0j}, V_{1j} distributions.

4.2.5 Calculation of Q_i Values:

The total measure of transformation $Q_{i,}$ is a function of q_{ji} (j = 1, 2, 3 and i = 1 to number of vehicle types) with the median speed $V_{1m,i}$, $V_{2m,i}$, $V_{3m,i}$ included as weighing factors.

$$Q_{iw} = \frac{q_{1,i}\, k_{1,i} + q_{2,i}\, k_{2,i} + q_{3,i}}{k_{1,i} + k_{2,i} + k_{3,i}}$$

$$k_{1,i} = \alpha_{1,i}(V_{0m,i} - V_{1m,i})$$

$$k_{2,i} = \alpha_{2,i}(V_{1m,i} - V_{2m,i})$$

$$k_{3,i} = \alpha_{3,i}(V_{2m,i} - V_{3m,i})$$

The value of Q_i describes the shape of the V_{3i} such that $V_{3i}^{Q_i}$ approximately distributed as $V_{0i}^{Q_i}$ minus shift d, which is dependent on all these factors. Hence the weighing

Hence we propose the following q_{ij} values are to calibrated.

For narrow lane roads and for each vehicle type:

1. q_{1j} for road width effect for different road width range.

2. q_{2j} for radius of curve effect for different radius of curve.

3. q_{3j} for roughness effect for different roughness limits.

The above mentioned procedure have been tried out for the calibration of Q_i values, but the results obtained were not satisfactory. Since the rotation parameter are calculated on the basis of BDS data(mean and standard deviation) and median block speed, the difference in means gives a measure of lateral shift and the difference in standard deviation gives the measure of rotation. The more the individual SD values, more is the dispersion and less the rotation. Again, each median block speed SD must be less than the SD of its BDS distribution because more the vehicle speed more is the SD. The data supplied by the CRRI were not consistent with respect to the above mentioned factors. The inconsistency in the data may be because of the following reasons:

i) The data that have been collected were not from the same location and horizontal curvature and roughness were

ii) The vehicles observed on different location were not the same vehicle.

Thus it is decided to calibrate the q_i values by trial and error i.e. we started with an assumed q_i value and a distribution is predicted. The predicted distribution is then compared with the actual distribution and their sum of squares of the difference is computed. The q_i value for which sum of the squares of the difference is minimum is adopted. The subsequent section explains the various steps involved in calibration.

4.3 Free speed study

Free speed model, as a sub-model of the main Traffic Simulation model, considers the effect of roadway parameters (i.e. roadwidth,curvature, roughness etc.) on the basic desired speed(BDS). Thus study of BDS and free speed of different types of vehicle becomes essential, as a prime input for the traffic simulation model.

As per the accepted definition in Traffic Engineering, basic desired speed, at which a driver would desire to drive his vehicle on a 2 - lane rural highway with wide hard shoulders, provided there are no obstructions due to traffic and the speed is not restricted by geometric

cell no FSS 315 satisfy all the conditions stated above and hence taken as basic desired speed.

4.3.1 Objectives

- To study the distribution of the basic desired speed (V_0) for each vehicle type.
- To estimate the median speed (V_3) and rotation parameter(Q) for each vehicle type

4.3.2 Scope of study

The scope of the study is confined to cover the following parameters

Type of roads :

The following type of roads are covered

- Single lane road
- Intermediate lane road
- Two lane road

Type of terrains:

The study will cover following two terrains

- Plain terrain
- Rolling terrain

Plain terrain for the purpose of study are

meters pr Km. and rolling terrain for total rise and fall between 15 to 40 meters per Km length of the road.

Type of Vehicles:

Vehicles to be covered are classified into following sub groups

- Light motor vehicles
  * Ambassador car
  * Premier Padmini
  * Maruti cars and vans
  * All makes of jeeps
  * Two wheelers (scooters and motorcycles)
- Heavy motor vehicles
  * Matadors and mini buses
  * All makes of buses
  * Light commercial vehicles
  * Trucks up to 12 tonne capacity
- Slow moving vehicle
  * Agricultural tractors

4.4 Calibration of q_i-Values

As it is stated earlier that, each roadway factor namely roadwidth, horizontal curve and pavement surface

Table 4.4.1 FRAMEWORK FOR FREE SPEED MEASUREMENT

ROAD TYPE		SINGLE LANE			INTERMEDIATE LANE			TWO LANE			FOUR LANE		
ROUGHNESS mm/Km.		LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THEN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000
TERRAIN	RADIUS OF CURVATURE (METERS)												
PLAIN	LESS THAN 150	FSC 111	FSC 121	FSC 131	FSC 211	FSC 221	FSC 231	FSC 311	FSC 321	FSC 331	FSC 411	FSC 421	FSC 431
	BETWEEN 150 AND 300	FSC 112	FSC 122	FSC 132	FSC 212	FSC 222	FSC 232	FSC 312	FSC 322	FSC 332	FSC 412	FSC 422	FSC 432
	BETWEEN 300 AND 450	FSC 113	FSC 123	FSC 133	FSC 213	FSC 223	FSC 233	FSC 313	FSC 323	FSC 333	FSC 413	FSC 423	FSC 433
	MORE THAN 450	FSC 114	FSC 124	FSC 134	FSC 214	FSC 224	FSC 234	FSC 314	FSC 324	FSC 334	FSC 414	FSC 424	FSC 434
	STRAIGHT	FSS 115	FSS 125	FSS 135	FSS 215	FSS 225	FSS 235	FSS 315	FSS 325	FSS 335	FSS 415	FSS 425	FSS 435
ROLLING	LESS THAN 150	FSC 116	FSC 126	FSC 136	FSC 216	FSC 226	FSC 236	FSC 316	FSC 326	FSC 336	-----	-----	-----
	BETWEEN 150 AND 300	FSC 117	FSC 127	FSC 137	FSC 217	FSC 227	FSC 237	FSC 317	FSC 327	FSC 337	-----	-----	-----
	BETWEEN 300 AND 450	FSC 118	FSC 128	FSC 138	FSC 218	FSC 228	FSC 238	FSC 318	FSC 328	FSC 338	-----	-----	-----
	MORE THAN 450	FSC 119	FSC 129	FSC 139	FSC 219	FSC 229	FSC 239	FSC 319	FSC 329	FSC 339	-----	-----	-----
	STRAIGHT	FSS 110	FSS 120	FSS 130	FSS 210	FSS 220	FSS 230	FSS 310	FSS 320	FSS 330	-----	-----	-----

INDICATES CELLS CONSIDERED FOR q1 CALIBRATION

INDICATES CELLS CONSIDERED FOR q2 CALIBRATION

q_i(i=1 for roadwidth effect, i=2 for curvature effect, i=3 for roughness effect). Thus it is necessary to calibrate q_i vales in order to estimate the total measure of rotation Q. The subsequent section explains the the various steps involved in calibration of q_i values.

4.4.1 Calibration of q_1 value

q1 represents rotation factor for road width alone. This is calibrated by using the transformation

$$V_{0i}^{q1} - V_{3i}^{q1} = V_{0m}^{q1} - V_{3m}^{q1}$$

$$\text{or} \quad V_{3i} = [V_0^{q1} - (V_{0m}^{q1} - V_{3m}^{q1})]^{1/q1}$$

Where V_{0m} = Median value of BDS

V_{3m} = Median value of free speed

V_{0i} =BDS at an arbitrary percentile

V_{3i} =Free speed at an arbitrary percentile

For calibrating q1 values for different vehicle types the mean and standard deviation given in the cells FSS315, FSS215 and FSS115 as shown in the Table 4.4.1 are taken and a two percentile distribution is generated. Using the transformation as given above V_{3i} values are predicted for the cells FSS115 and FSS215. The predicted values are then

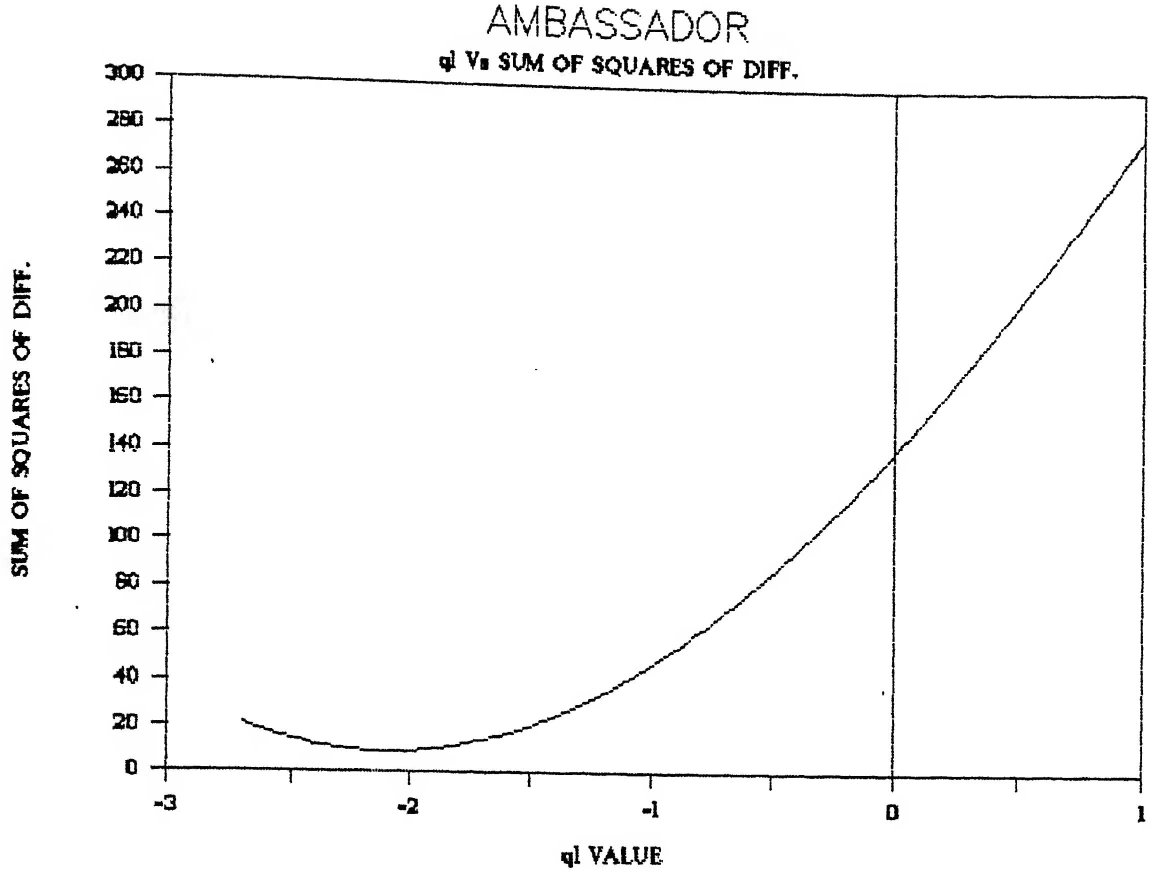


Fig. 4.4.1

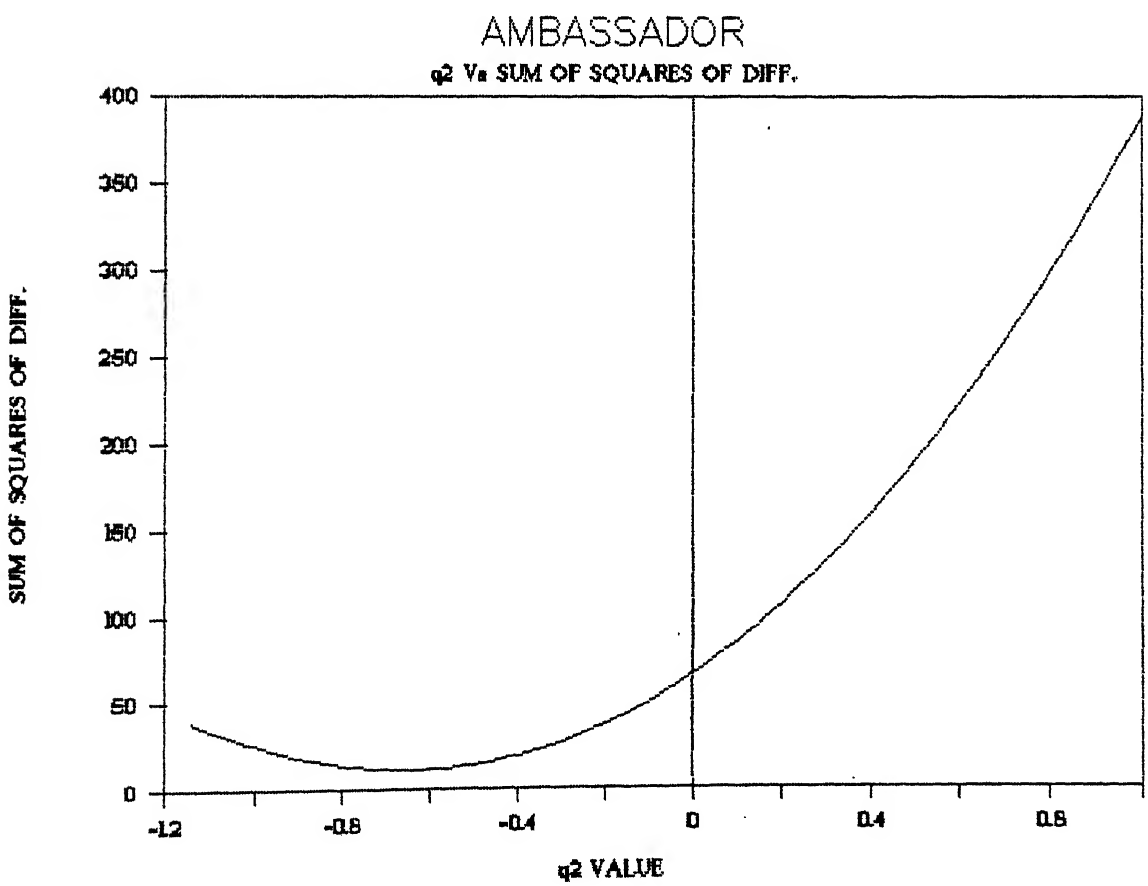


Fig. 4.4.2

of the difference for both the cells are computed. Initially q1 value is assumed to be 1.0 and it is then decremented by 0.02 after each iteration. The value of q1 for which sum of the squares of the difference is minimum is adopted as q1. Fig.4.4.1 shows the plot between q1 and total sum of squares of the difference. The procedure is repeated for each vehicle types.

4.4.2 Calibration of q_2 value

q2 represents the rotation factor for horizontal curvature alone. This is also calibrated by using the transformation

$$V_{3i}=[v_{0i}^{q2}-(v_{0m}^{q2}-V_{3m}^{q2})]^{1/q2}$$

For calibrating q2 values for different vehicle types the mean and standard deviation given in the cells FSC311, FSC312,FSC313,FSC314 as shown in the Table4.4.1 are taken and two percentile distribution is generated for each of thecells.Using the transformation stated above V_{3i} values are predicted for the cells FSC311,FSC312, FSC313, FSC314. The predicted values are then compared with the field data and their total sum of the square of the difference for all the cells are computed. Here also initially q2 value is assumed to be 1.0 and it is then decremented by 0.02 after each iteration. The value of the q2 for which total sum of the squares is minimum is adopted. Fig.4.4.2 shows the plot

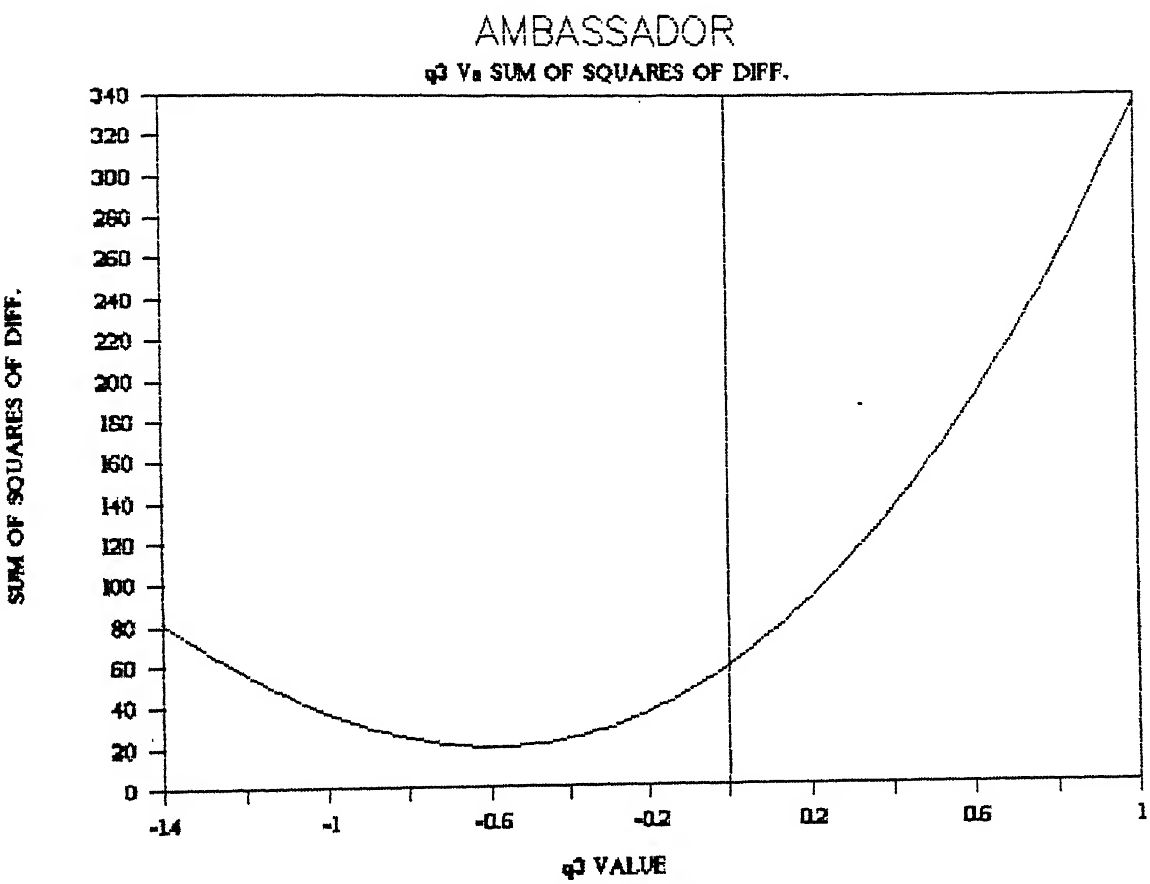

AMBASSADOR
q3 Vs SUM OF SQUARES OF DIFF.
SUM OF SQUARES OF DIFF.
q3 VALUE
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-1.4
-1
-0.6
-0.2
0.2
0.6
1

Fig. 4.4.3

procedure is repeated for all vehicle types.

4.4.3 Calibration of q_3 value

q3 represents rotation factor for surface roughness alone. This is also done by using the transformation

$$V_{3i}=[V_{0i}^{q3}-(V_{0m}^{q3}-V_{3m}^{q3})]^{1/q3}$$

For calibrating q3 values for each of the vehicle types the mean and standard deviation given in the cells FSS315, FSS325 and FSS335 are taken as shown in the Table 4.4.1 and two percentile distribution is generated. Using the transformation as given above, V_{3i} values are predicted for the cells FSS325 and FSS335 . The predicted values are then compared with the field data and their sum of squares of the differences are computed. Here also an initial value of q3 is assumed as 1.0 and it is then decremented by 0.02 after each iteration. The q3 value for which sum of the squares of the difference is minimum is adopted. Fig.4.4.3 shows the plot between q3 and sum of squares of the difference. The procedure is repeated for each vehicle types.

4.5 Calibration of α value

The total measure of rotation of Q is a function of q1, q2, and q3 with median speeds V_{1m}, V_{2m}, V_{3m} included as

Table 4.4.2 FRAMEWORK FOR FREE SPEED MEASUREMENT

ROAD TYPE		SINGLE LANE			INTERMEDIATE LANE			TWO LANE			FOUR LANE		
ROUGHNESS mm/Km.		LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THEN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000	LESS THAN 3000	BETWEEN 3000 AND 6000	MORE THAN 6000
TERRAIN	RADIUS OF CURVATURE (METERS)												
PLAIN	LESS THAN 150	FSC 111	FSC 121	FSC 131	FSC 211	FSC 221	FSC 231	FSC 311	FSC 321	FSC 331	FSC 411	FSC 421	FSC 431
	BETWEEN 150 AND 300	FSC 112	FSC 122	FSC 132	FSC 212	FSC 222	FSC 232	FSC 312	FSC 322	FSC 332	FSC 412	FSC 422	FSC 432
	BETWEEN 300 AND 450	FSC 113	FSC 123	FSC 133	FSC 213	FSC 223	FSC 233	FSC 313	FSC 323	FSC 333	FSC 413	FSC 423	FSC 433
	MORE THAN 450	FSC 114	FSC 124	FSC 134	FSC 214	FSC 224	FSC 234	FSC 314	FSC 324	FSC 334	FSC 414	FSC 424	FSC 434
	STRAIGHT	FSS 115	FSS 125	FSS 135	FSS 215	FSS 225	FSS 235	FSS\315	FSS 325	FSS 335	FSS 415	FSS 425	FSS 435
ROLLING	LESS THAN 150	FSC 116	FSC 126	FSC 136	FSC 216	FSC 226	FSC 236	FSC 316	FSC 326	FSC 336	-----	-----	-----
	BETWEEN 150 AND 300	FSC 117	FSC 127	FSC 137	FSC 217	FSC 227	FSC 237	FSC 317	FSC 327	FSC 337	-----	-----	-----
	BETWEEN 300 AND 450	FSC 118	FSC 128	FSC 138	FSC 218	FSC 228	FSC 238	FSC 318	FSC 328	FSC 338	-----	-----	-----
	MORE THAN 450	FSC 119	FSC 129	FSC 139	FSC 219	FSC 229	FSC 239	FSC 319	FSC 329	FSC 339	-----	-----	-----
	STRAIGHT	FSS 110	FSS 120	FSS 130	FSS 210	FSS 220	FSS 230	FSS 310	FSS 320	FSS 330	-----	-----	-----

INDICATES CELLS CONSIDERED FOR $\alpha 2$ CALIBRATION

INDICATES CELLS CONSIDERED FOR $\alpha 3$ CALIBRATION

$$Q = \frac{q_1\ k_1 + q_2\ k_2 + q_3\ k_3}{k_1 + k_2 + k_3}$$

Where $k_1 = \alpha 1(V_{0m} - V_{1m})$

$k_2 = \alpha 2(V_{1m} - V_{2m})$

$k_3 = \alpha 3(V_{2m} - V_{3m})$

V_{0m}, V_{1m}, V_{2m} and V_{3m} are the median speeds.

4.5.1 Value of α_1

Here assumed value of $\alpha 1$ is taken as 1 for all types of vehicles.

4.5.2 Calibration of α_2

When only road width and curvature effects are taken into consideration the expression for Q reduces to

$$Q = \frac{\alpha_1(V_{0m} - V_{1m})\ q_1 + \alpha_2(V_{1m} - V_{2m})\ q_2}{\alpha 1(V_{0m} - V_{1m}) + \alpha 2(V_{1m} - V_{2m})}$$

In the above expression only $\alpha 2$ and Q values are unknown. To calibrate the $\alpha 2$ values for different vehicle types we assumed a positive value for $\alpha 2$ and Q value is computed from the above expression. Once Q is calculated V_{3i} values for the

cells FSC112, FSC113, FSC114, FSC211, FSC212, FSC213, FSC214 FSC311, FSC312, FSC313, and FSC314 as shown in the Table 4.4.2 are predicted. The predicted values are compared with the field values and their total sum of squares of the differences is computed. The $\alpha 2$ value is incremented by 0.02 after each iteration. A graph is plotted between $\alpha 2$ values vs their corresponding total sum of the squares of the differences as shown in the Fig.4.5.2. From the plot it is observed that after certain value of $\alpha 2$, the decrease of the sum of squares of difference is very small with the increase of $\alpha 2$. The point at which the decrease of the sum of the squares of the difference becomes very small is identified and the corresponding $\alpha 2$ value is taken as the accepted value.

4.5.3 Calibration of α_3

When all the factors namely roadwidth, horizontal curvature and surface roughness are taken into consideration, the expression for Q reduces to

$$Q = \frac{\alpha 1(V_{0m} - V_{1m})q1 + \alpha 2(V_{1m} - V_{2m})q2 + \alpha 3(V_{2m} - V_{3m})q3}{\alpha 1(V_{0m} - V_{1m}) + \alpha 2(V_{1m} - V_{2m}) + \alpha 3(V_{2m} - V_{3m})}$$

In the above expression only $\alpha 3$ and Q values are

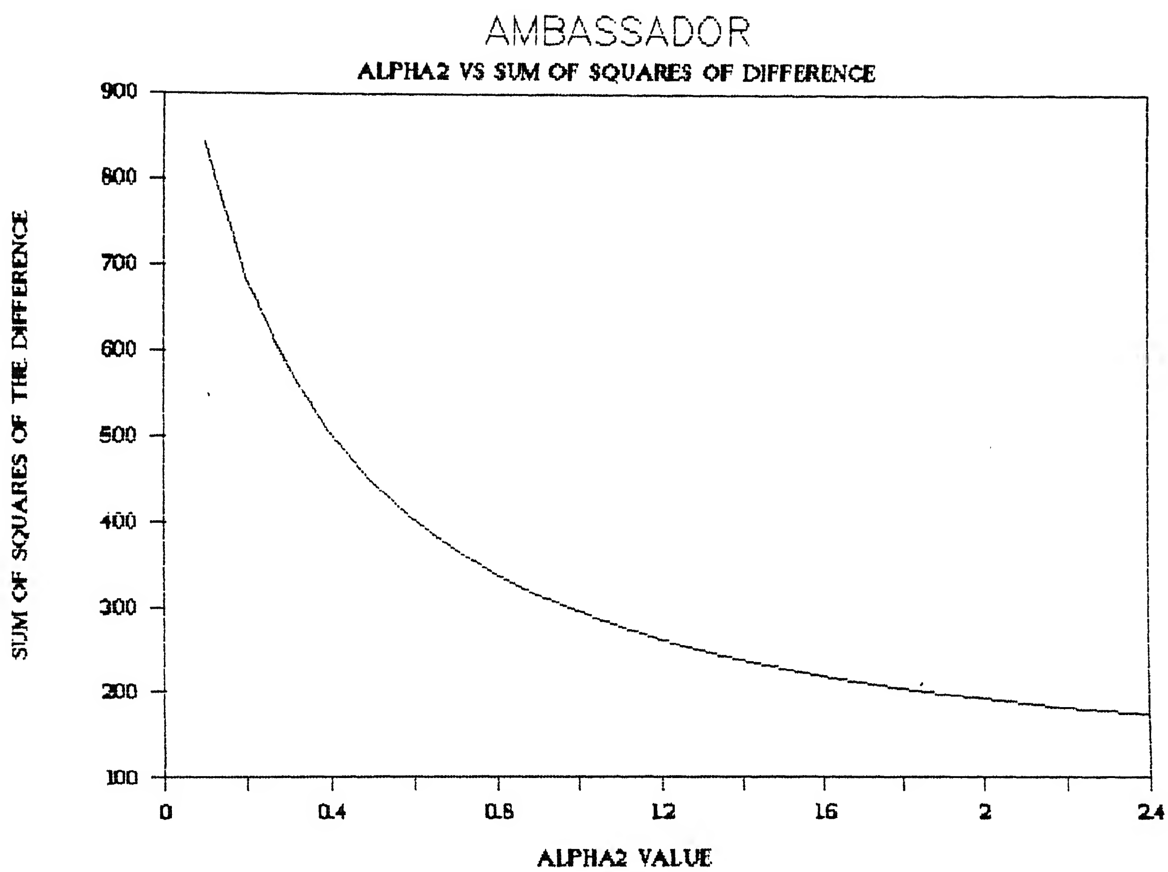


Fig. 4.5.2

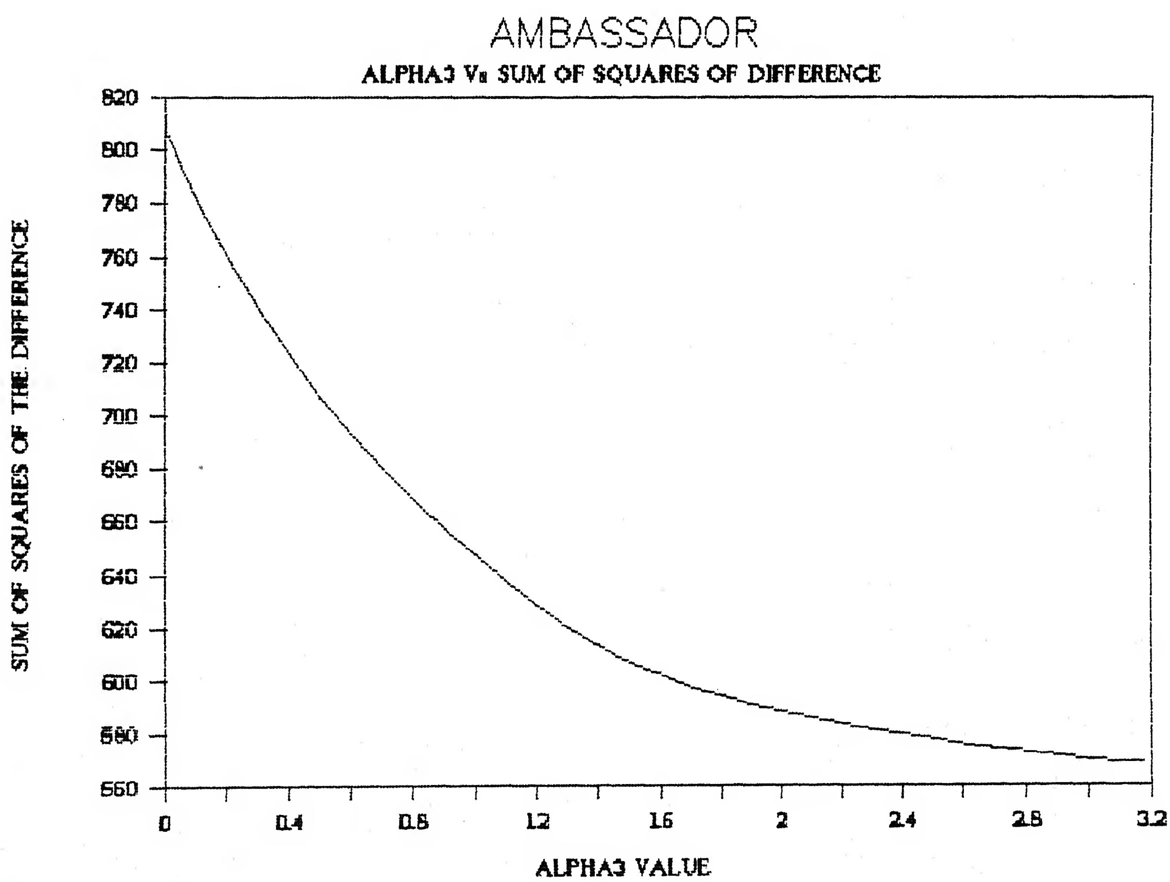


Fig. 4.5.3

unknown. To calibrate $\alpha3$ values for all the vehicle types we assume a positive value for $\alpha3$ and the corresponding Q value is computed. Using this Q value V_{3i} values for the cells FSC122,FSC123,FSC124,FSS125,FSC132,FSC133,FSC134,FSS135, FSC221,FSC222,FSC223,FSC224, FSS225,FSC231,FSC232, FSC233, FSC234, FSS235as shown in the Table 4.4.2 are predicted. The predicted values are then compared with the field values and their total sum of squares squares of the differences is computed. A graph is plotted between $\alpha3$ and the total sum of squares of the differences as shown in the Fig.4.5.3. From the graph it is observed that at a particular value of $\alpha3$, the decrease of the sum of the squares of difference becomes very small and that value is taken as α_3.

The calibrated values of q_1, q_2, q_3, α_1, α_2, $\alpha_3$and Q values Ambassador car have been shown in the Table 4.2.

This chapter explained in detail the various steps involved in calibration of Q value. The plot between field distribution and predicted distribution for Ambassador car in plain terrain with the calibrated Q values have been shown in Fig. 4.1 to 4.14.

Next chapter explains the various experiments that have been carried out to validate the simulation model. The comparison between simulated and field data have been done in that chapter.

TABLE 4.2 COMPUTED Q VALUES FOR DIFFERENT ROAD SECTIONS

VEH.TYPE: AMBASSADOR TERRAIN: PLAIN

q1= -1.96 q2= -0.60 q3= -0.58

α1= 1.0 α2= 2.0 α3= 2.50

SINGLE LANE ROADWAY

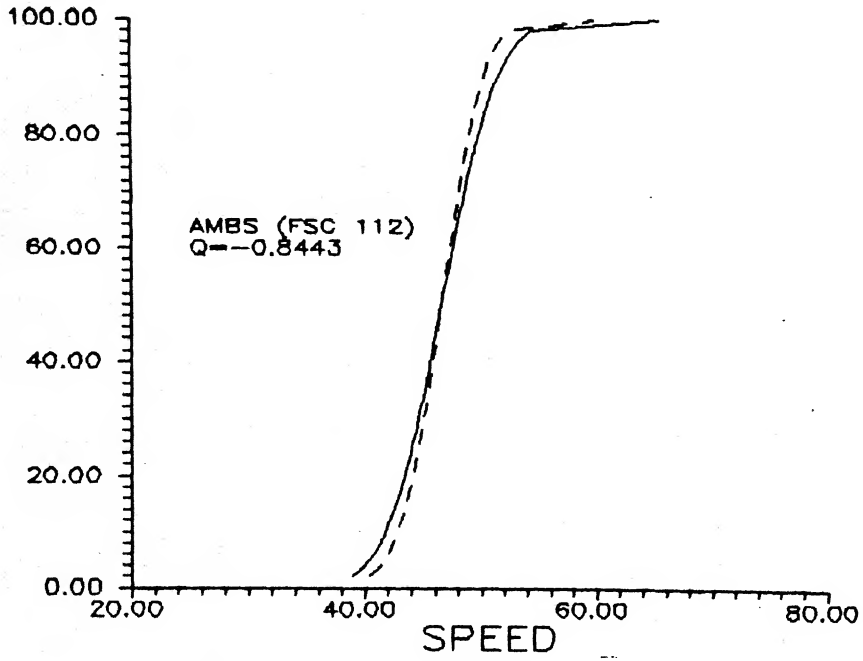
Q112= -0.8443244	Q122= -0.7101527	Q132= -0.7303935
Q113= -0.9362803	Q123= -0.8111144	Q133= -0.7374662
Q114= -1.139228	Q124= -0.8443119	Q134= -0.8443119
Q115= -1.960000	Q125= -0.8906376	Q135= -0.7550169

INTERMEDIATE LANE ROADWAY

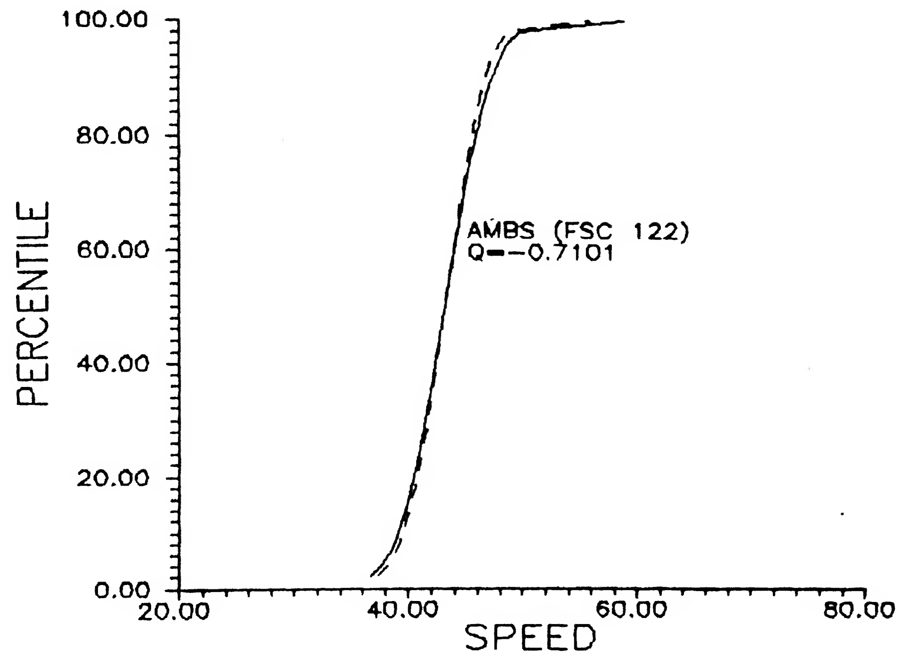
Q211= -0.7572280	Q221= -0.7247202	Q231= -0.6891277
Q212= -0.7667383	Q222= -0.7305164	q232= -0.6861406
Q213= -0.8355168	Q223= -0.7514471	Q233= -0.6938245
Q214= -1.0015040	Q224= -0.7810684	Q234= -0.7033269
Q215= -1.9600000	Q225= -0.8266272	Q235= -0.7154139

TWO LANE ROADWAY

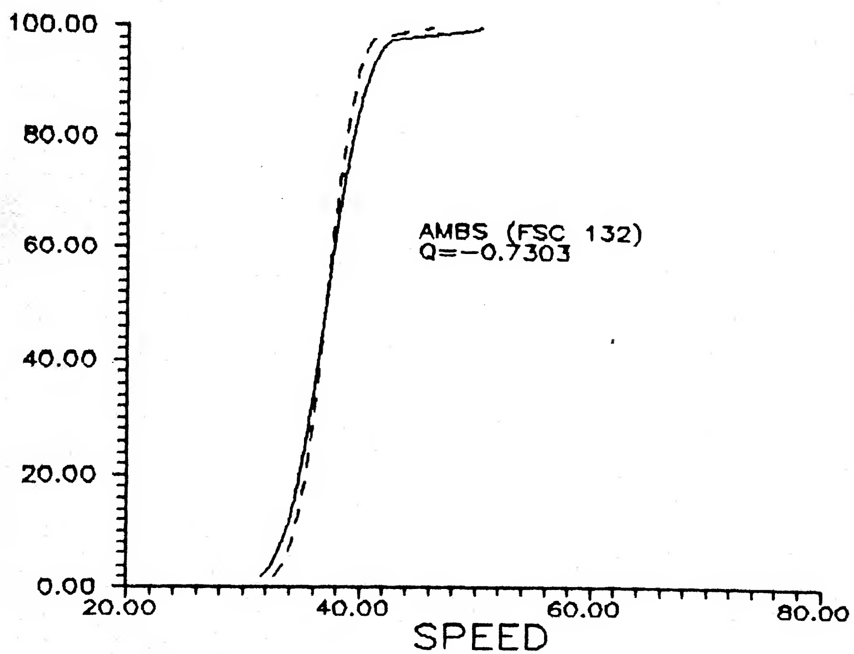
Q311= -0.6000000	Q321= -0.5954270	Q331= -0.5915509
Q312= -0.6000000	Q322= -0.5949986	Q332= -0.5900677
Q313= -0.6000000	Q323= -0.5927517	Q333= -0.5882329



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

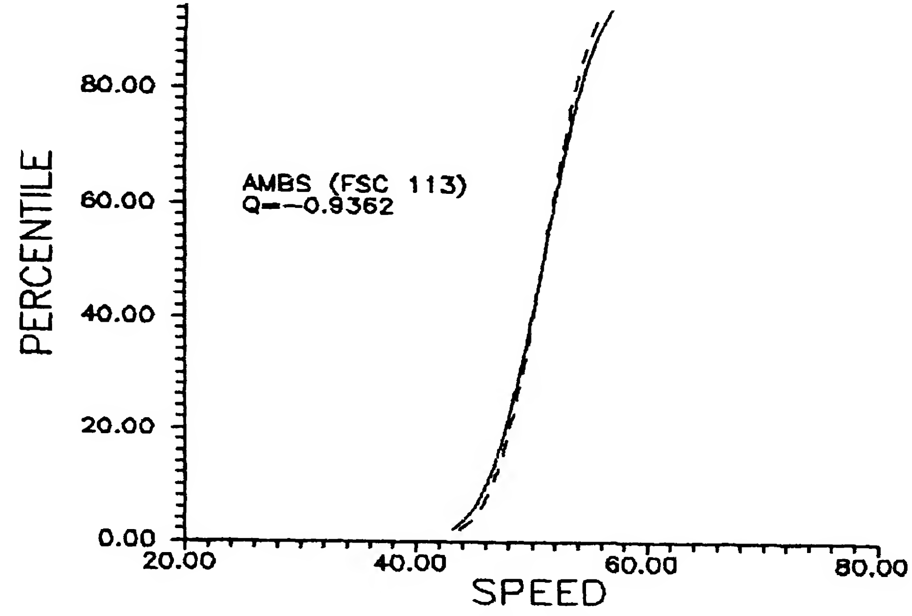
LANE WIDTH: 3.5m (SL) , TERRAIN : PLAIN

RADIUS OF CURVATURE : LESS THAN 300m

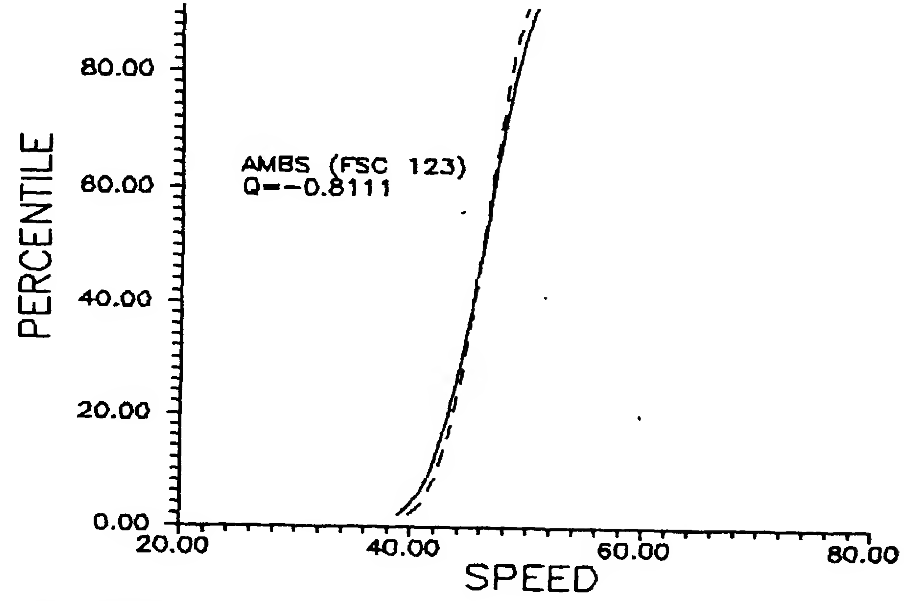
———————— REPRESENTS FIELD DATA

\- - - - - - - - REPRESENTS PREDICTED DATA

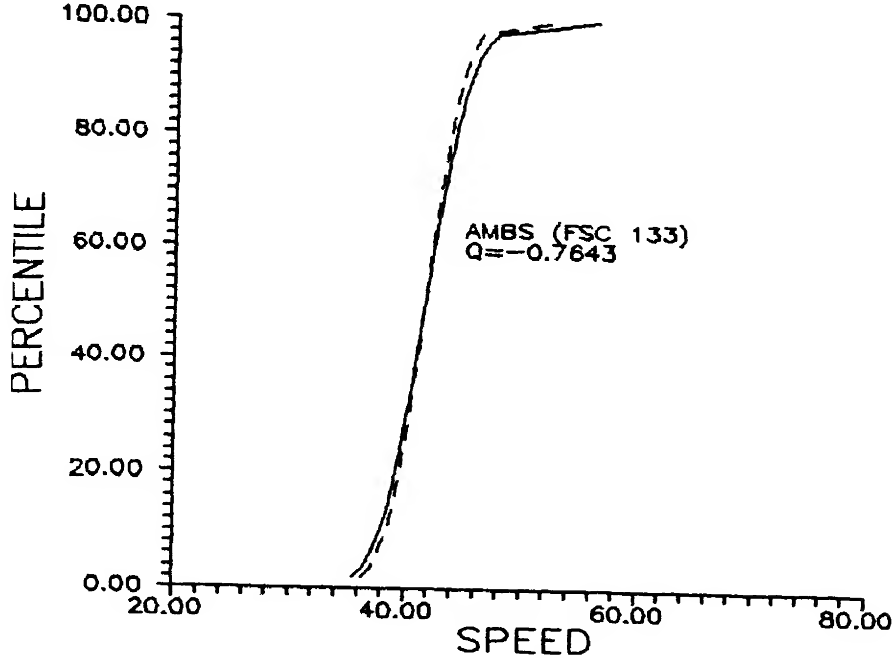
FIG.4.1



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

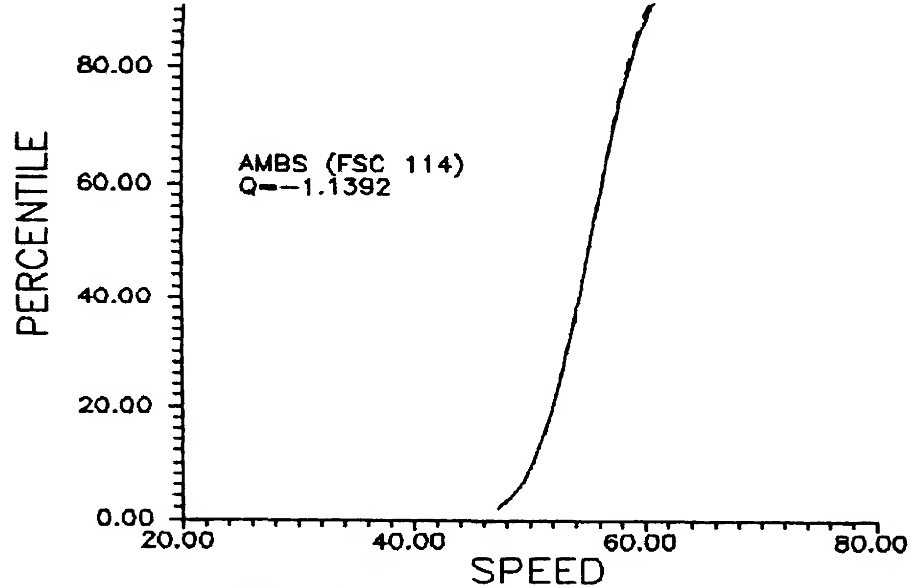
LANE WIDTH:3.5m (SL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :BETWEEN 300m TO 450m

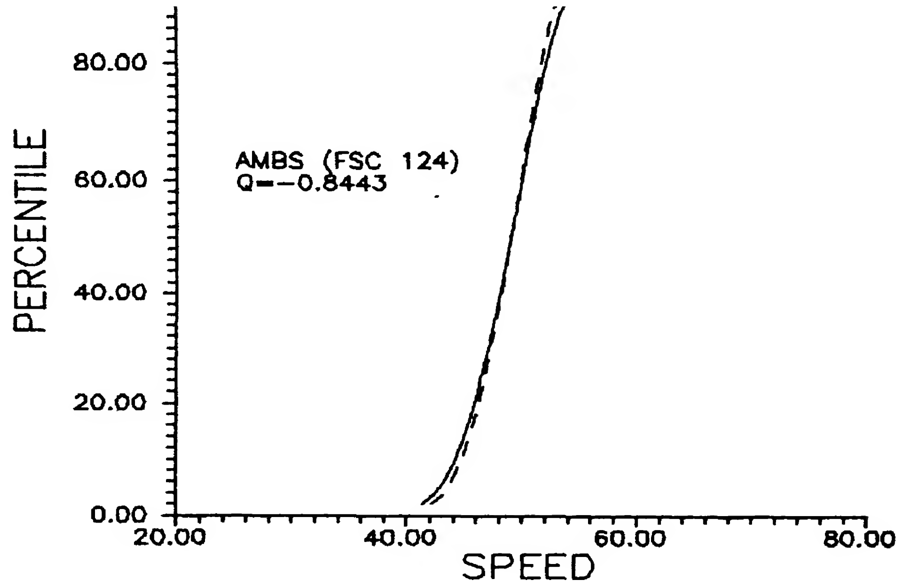
———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

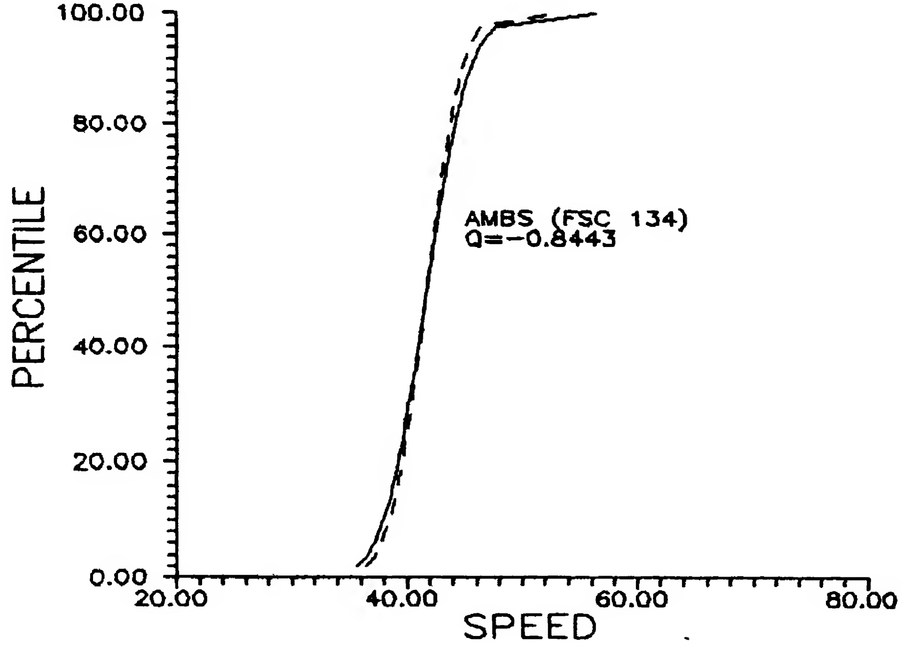
FIG.4.2



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

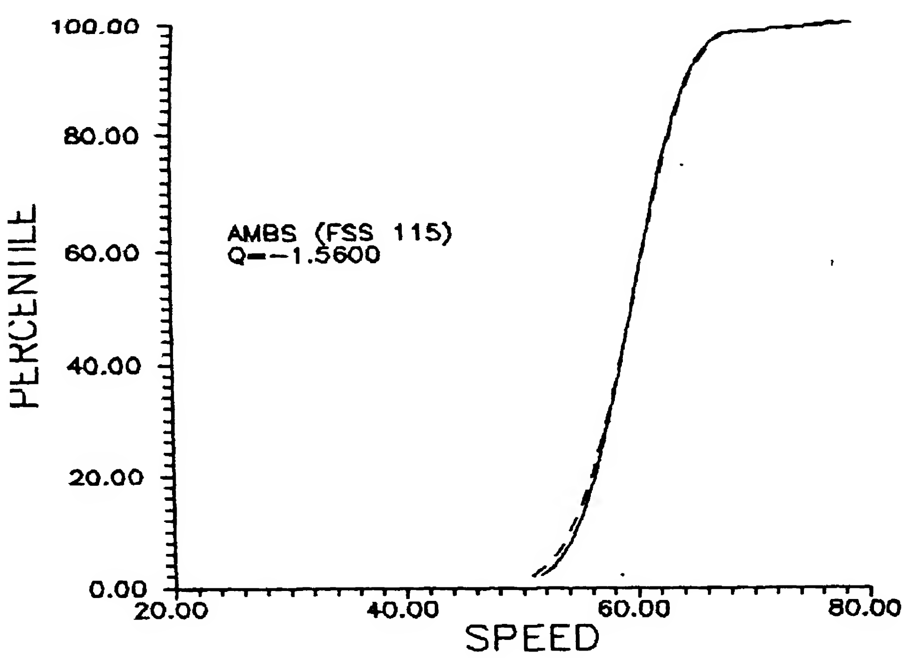
LANE WIDTH: 3.5m (SL) , TERRAIN : PLAIN

RADIUS OF CURVATURE : BETWEEN 450m AND 1000m

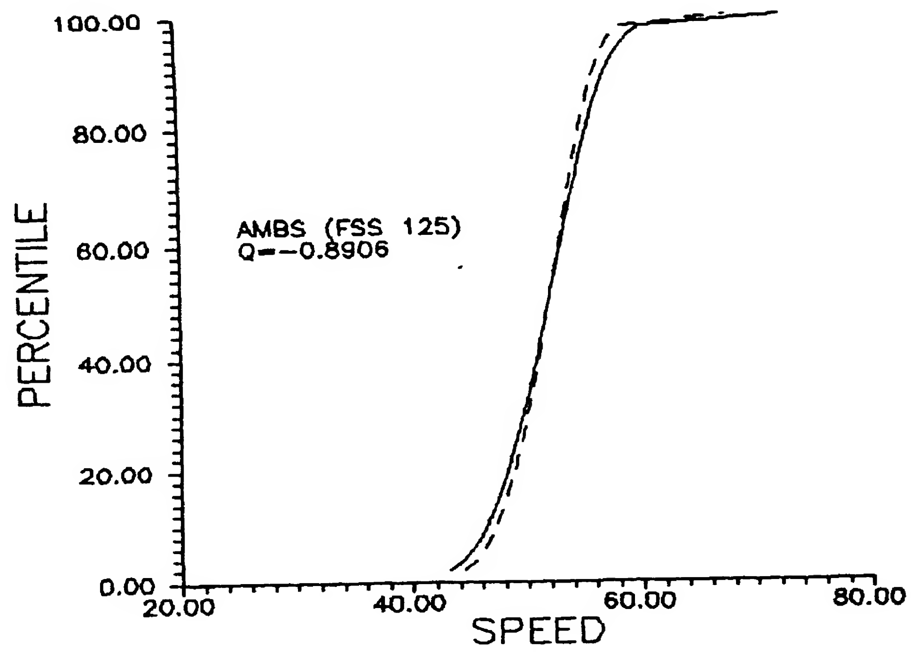
———— REPRESENTS FIELD DATA

- - - - - - REPRESENTS PREDICTED DATA

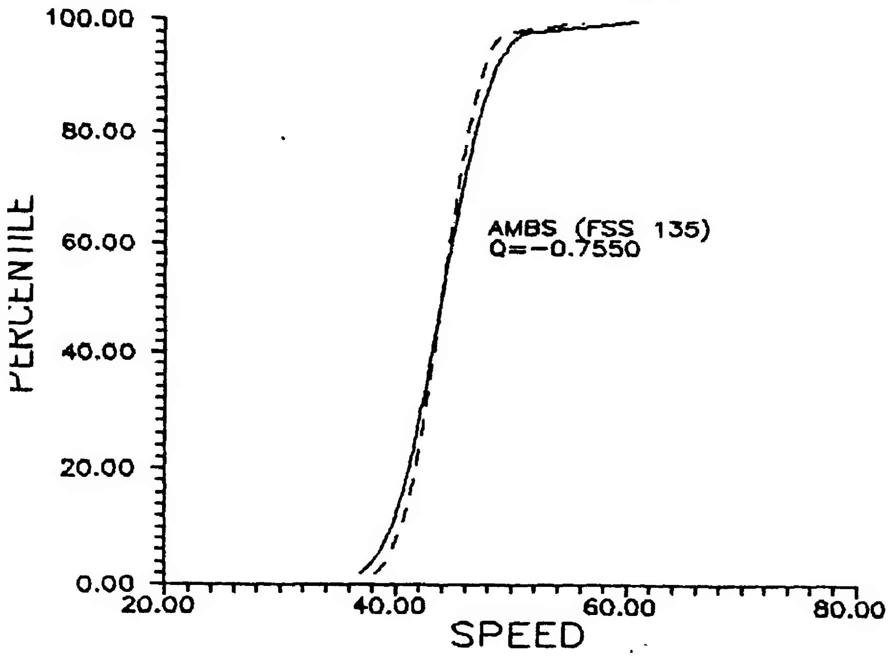
FIG.4.3



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

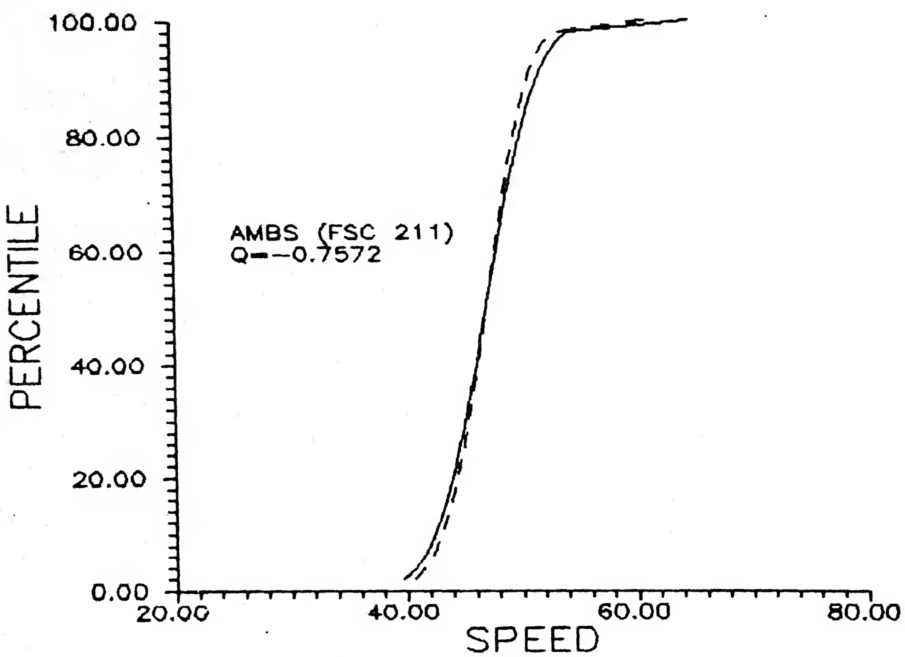
LANE WIDTH:3.5m (SL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :STRAIGHT ROAD

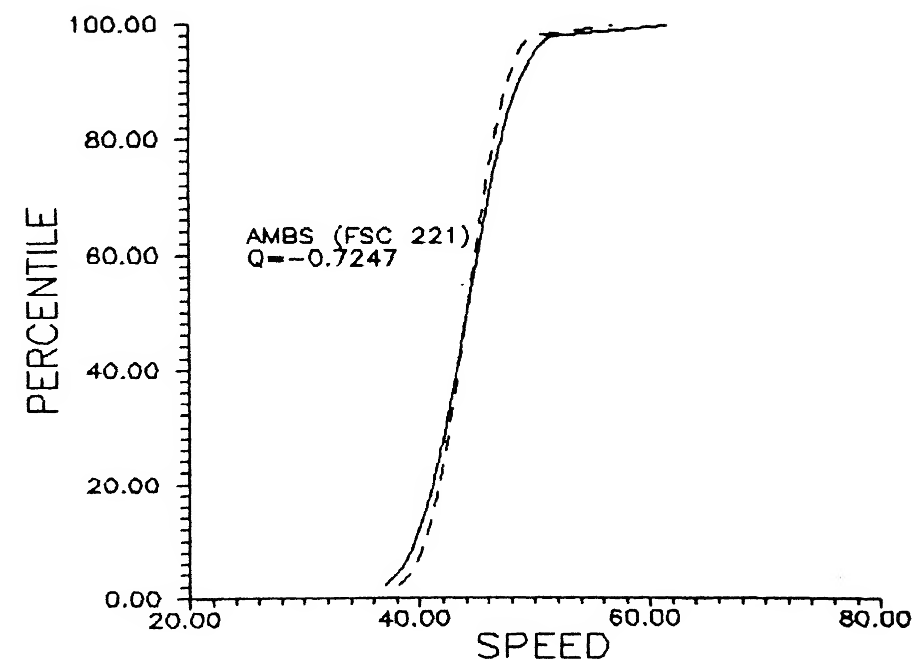
———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

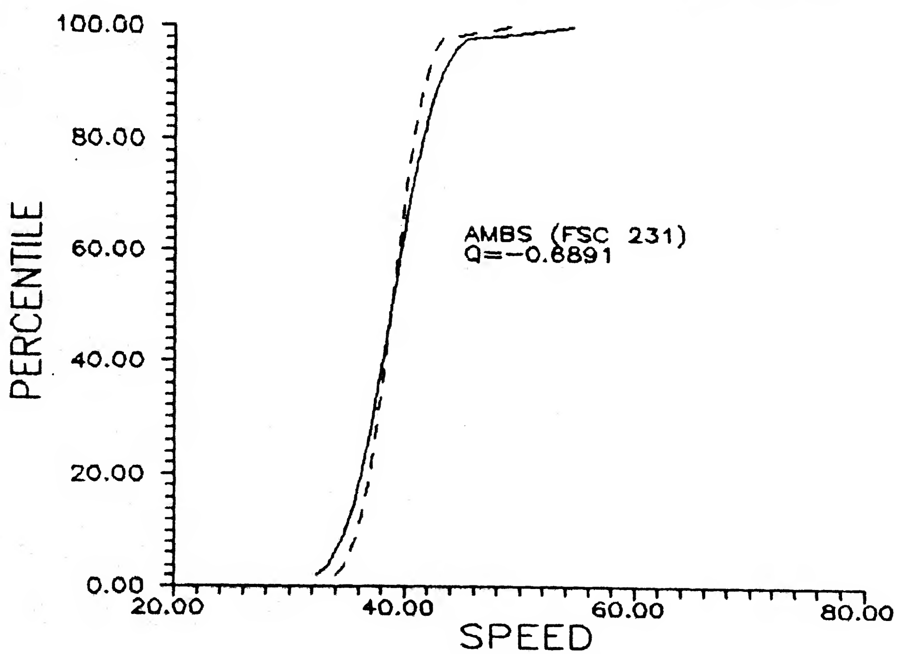
FIG.4.4



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

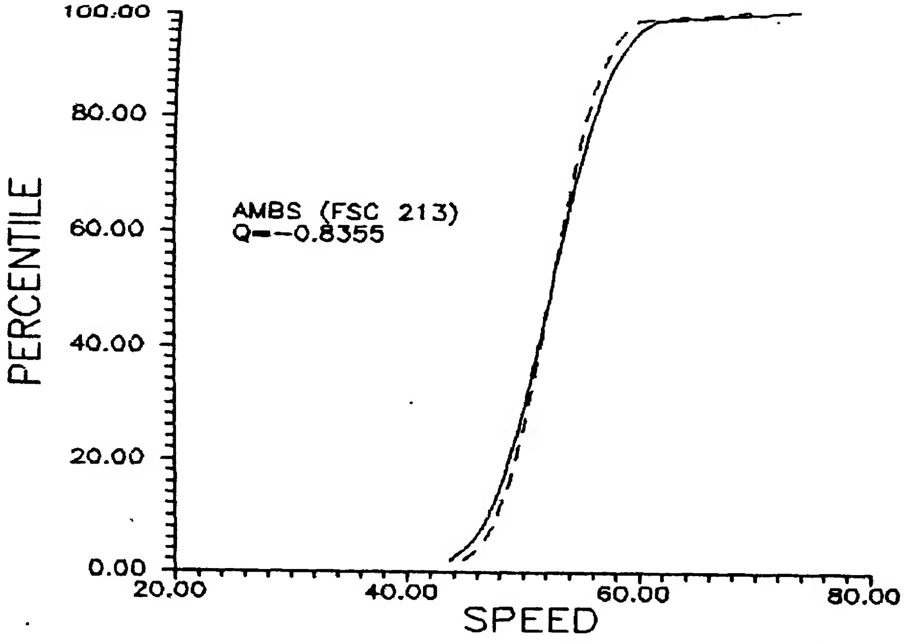
LANE WIDTH:5.5m (SL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :LESS THAN 150m

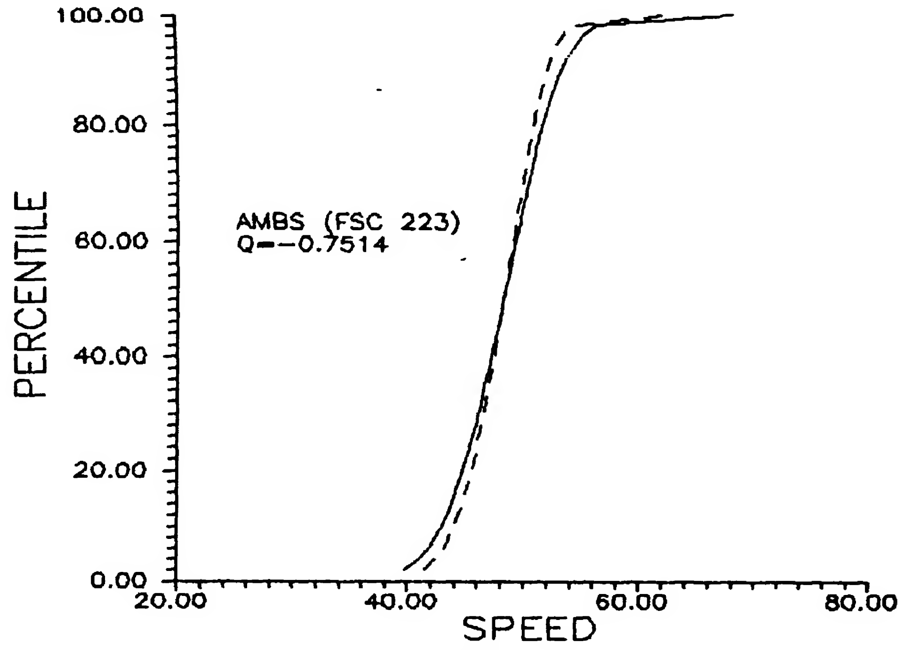
———————— REPRESENTS FIELD DATA

\- - - - - - - REPRESENTS PREDICTED DATA

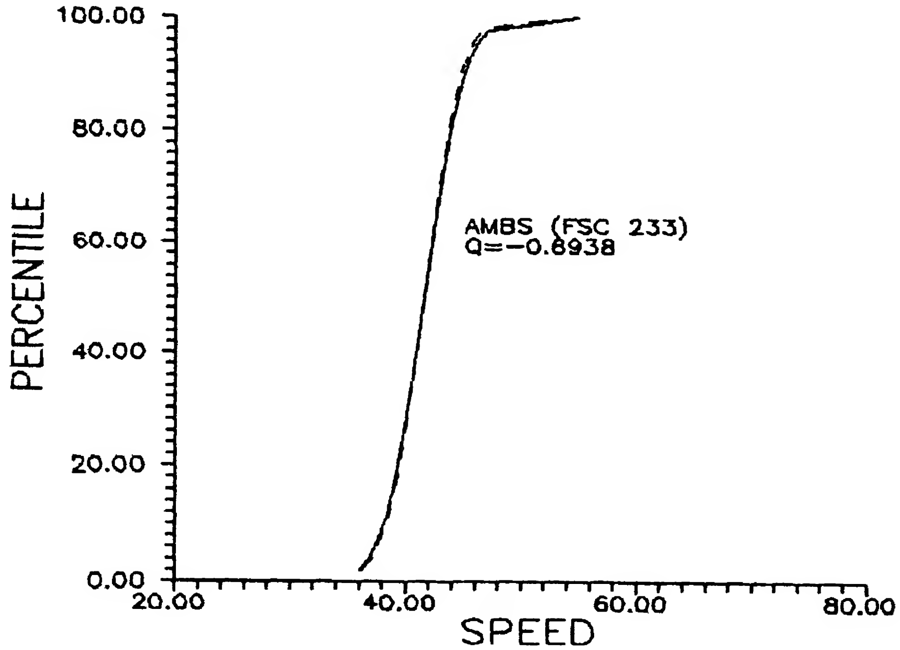
FIG.4.5



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

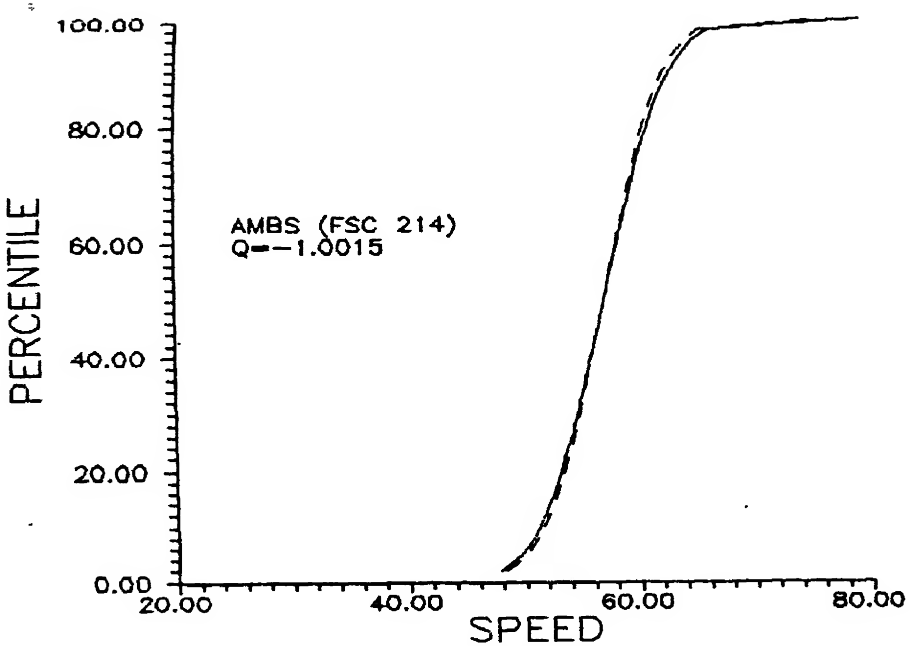
LANE WIDTH: 5.5m (IL) , TERRAIN : PLAIN

RADIUS OF CURVATURE : BETWEEN 300m AND 450m

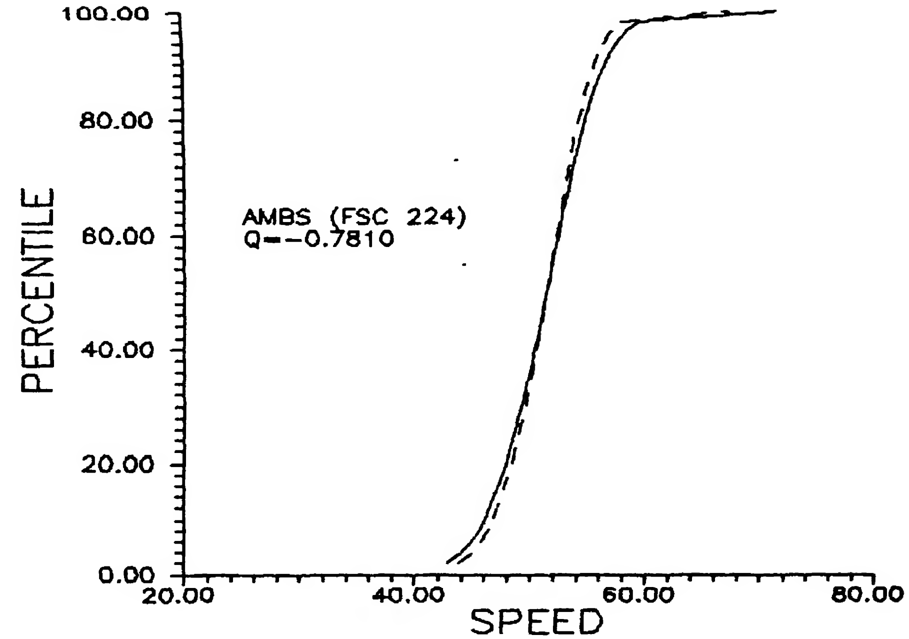
———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

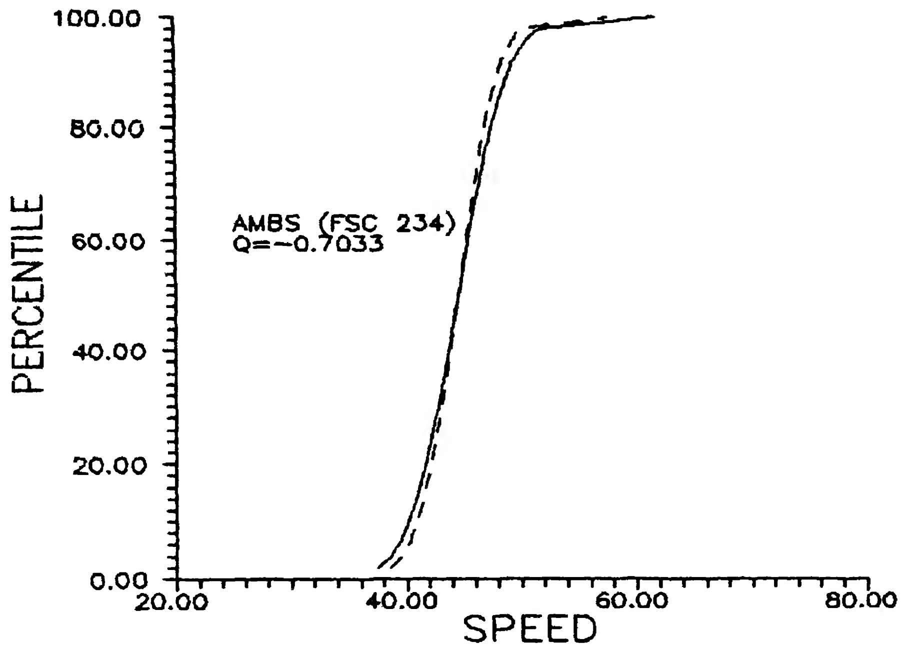
FIG.4.7



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

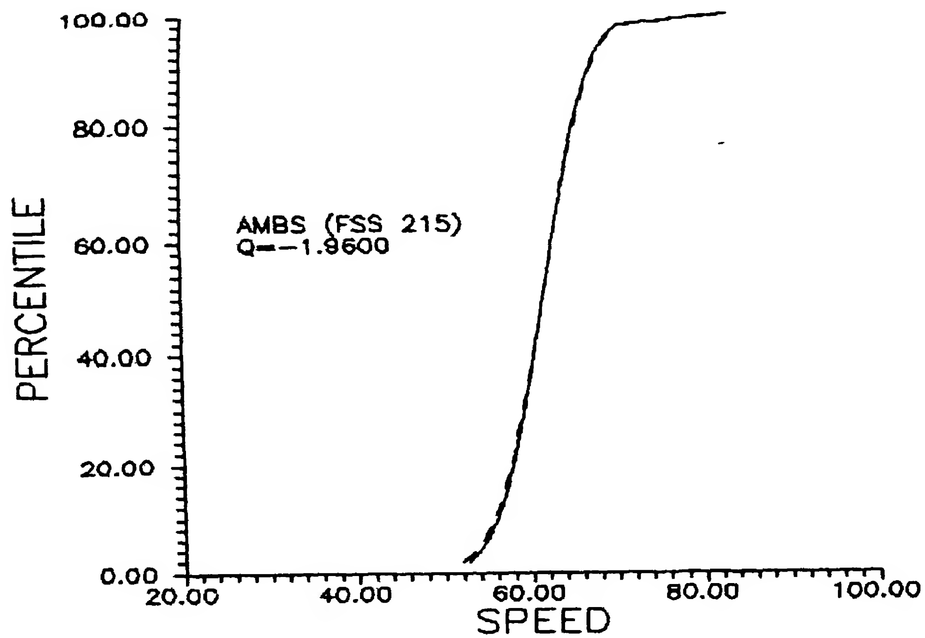
LANE WIDTH:5.5m (IL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :BETWEEN 450m AND 1000m

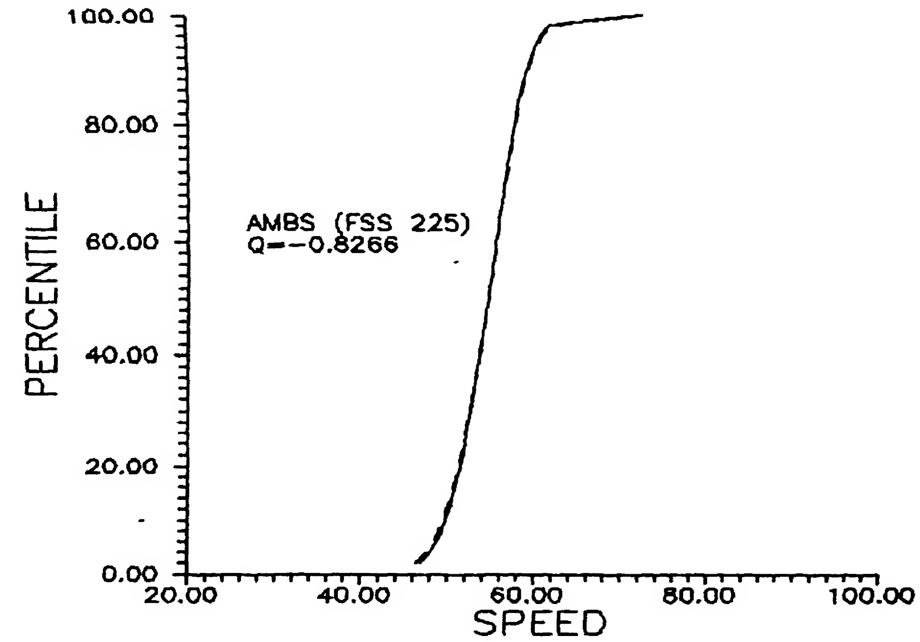
———————— REPRESENTS FIELD DATA

- - - - - - - - REPRESENTS PREDICTED DATA

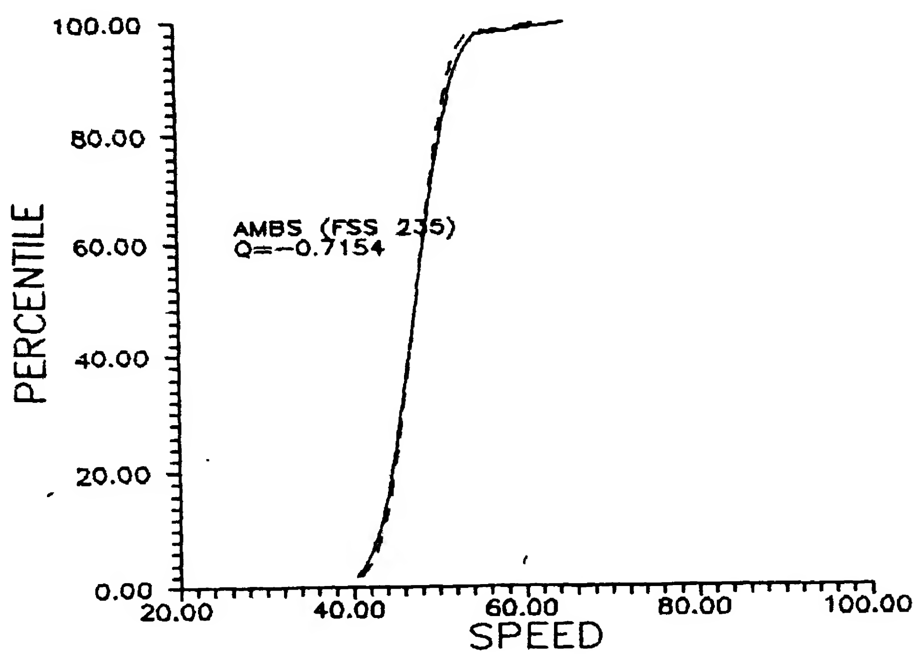
FIG.4.8



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

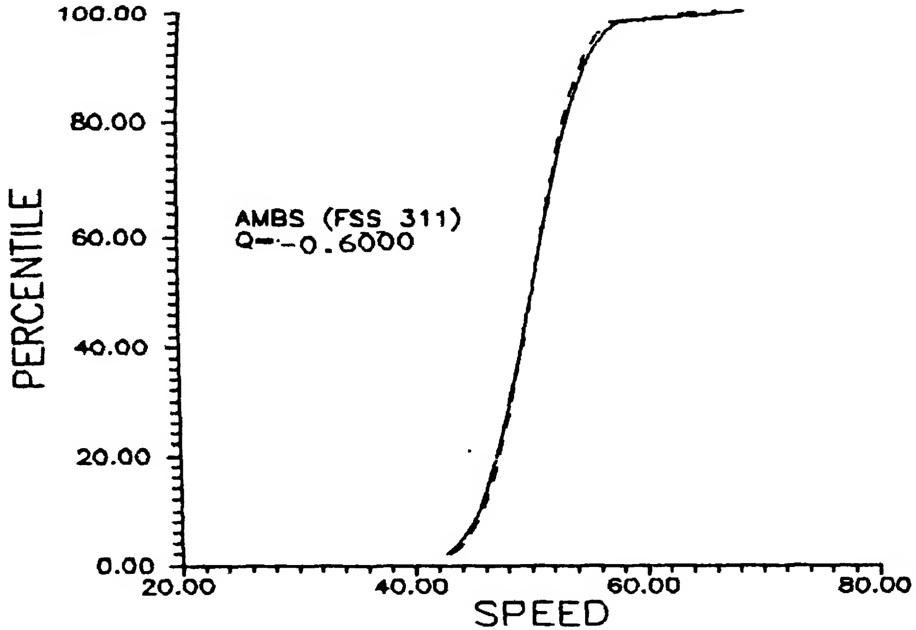
LANE WIDTH:5.5m (IL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :STRAIGHT ROAD

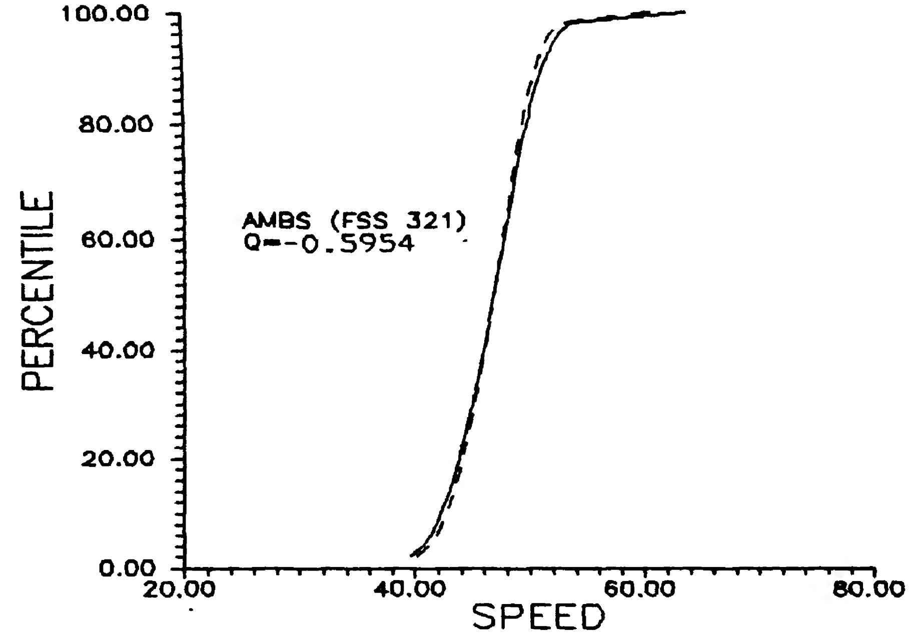
———————— REPRESENTS FIELD DATA

\- - - - - - - - REPRESENTS PREDICTED DATA

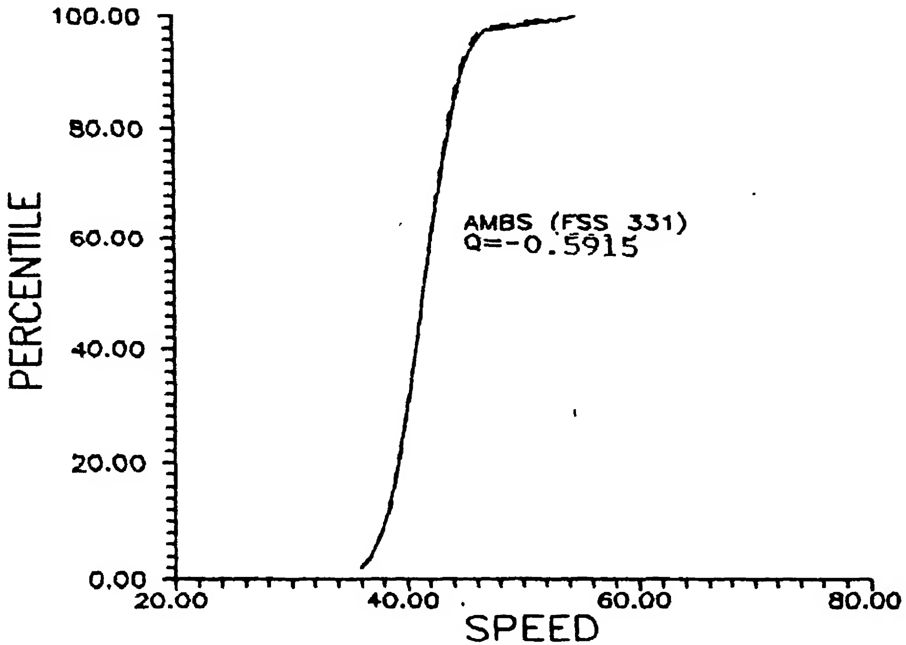
FIG.4.9



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

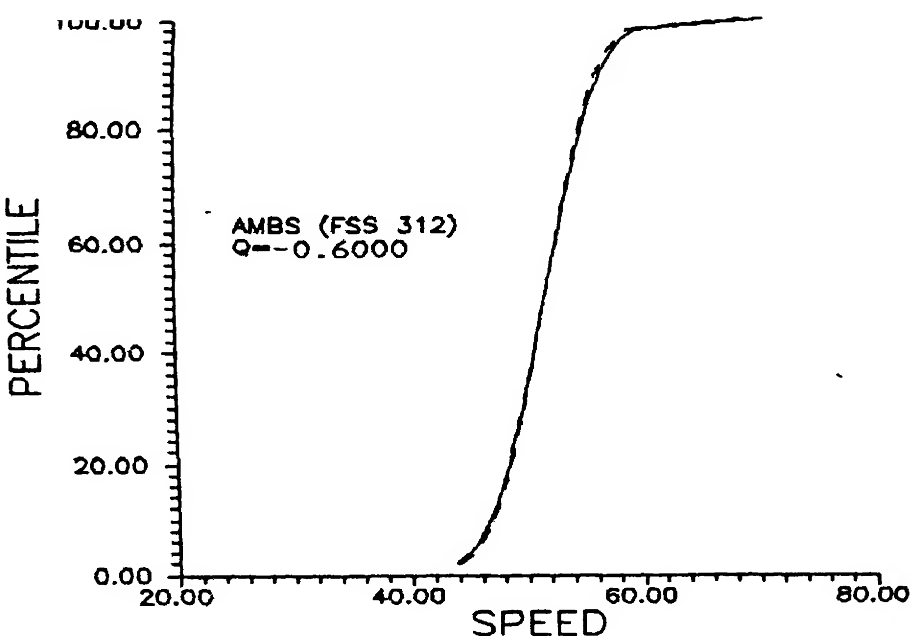
LANE WIDTH:7.0m (TL) , TERRAIN :PLAIN

RADIUS OF CURVATURE :LESS THAN 150m

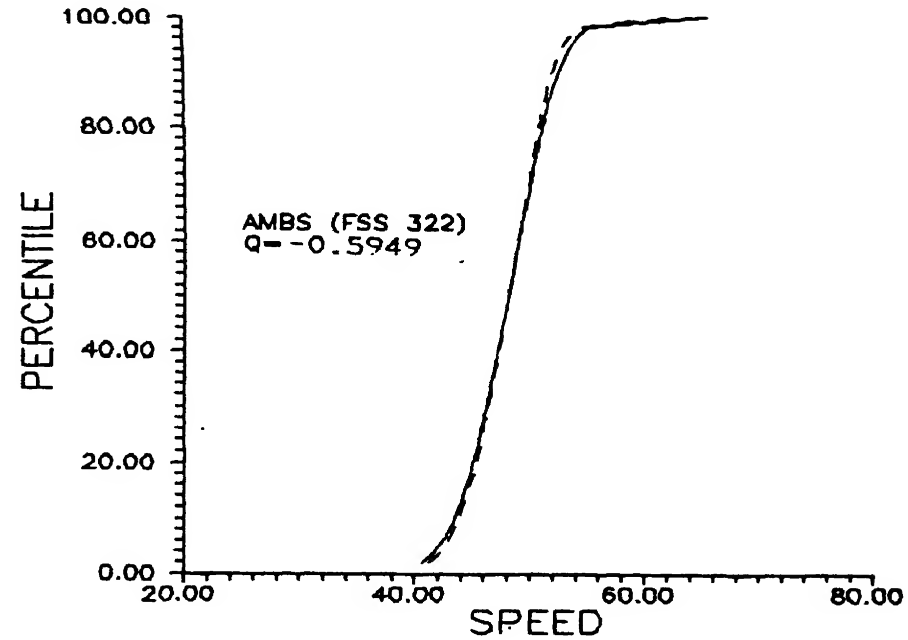
——————— REPRESENTS FIELD DATA

- - - - - - - - REPRESENTS PREDICTED DATA

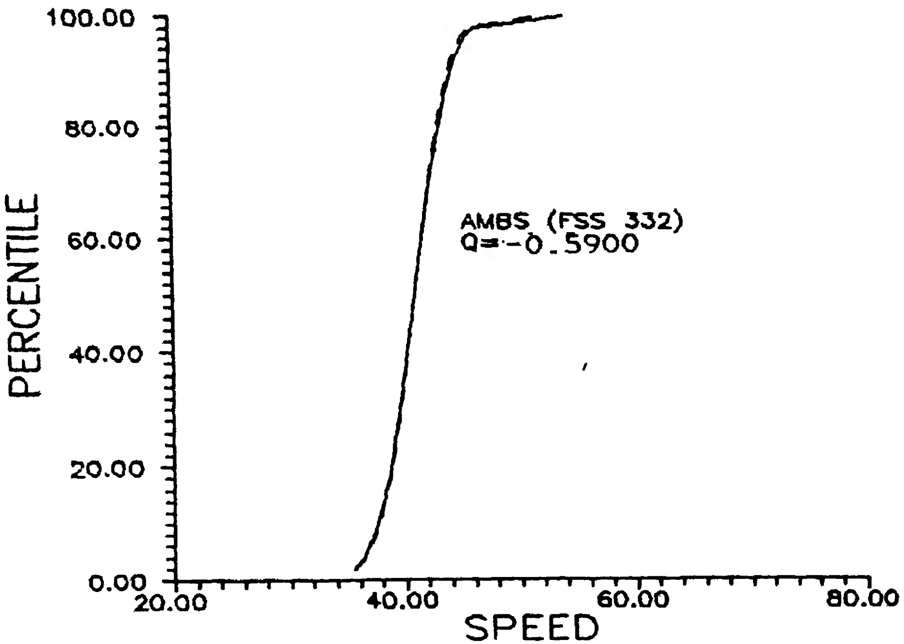
FIG.4.10



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

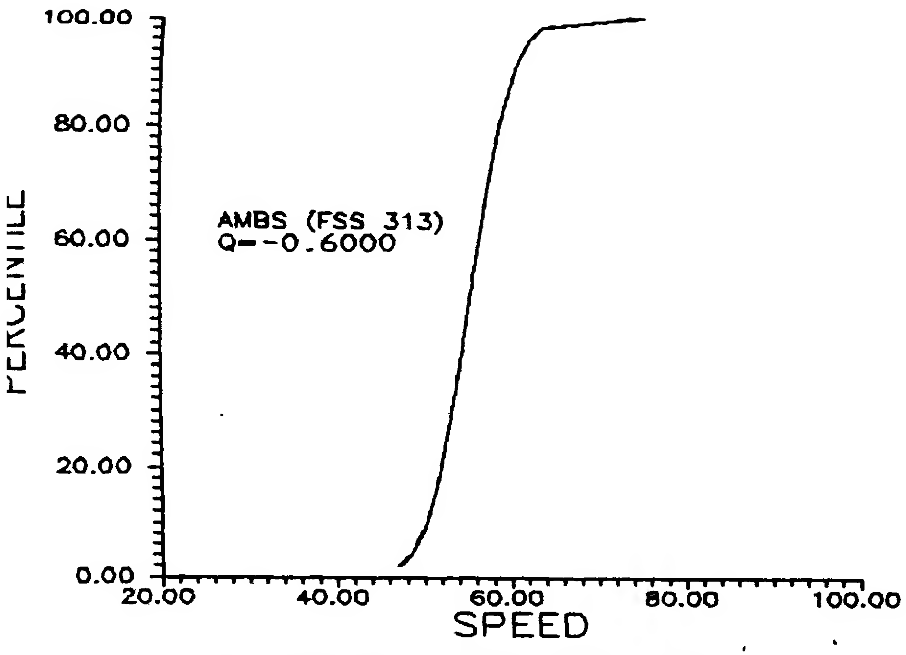
LANE WIDTH:7.0m , TERRAIN : PLAIN

RADIUS OF CURVATURE :BETWEEN 150m AND 300m

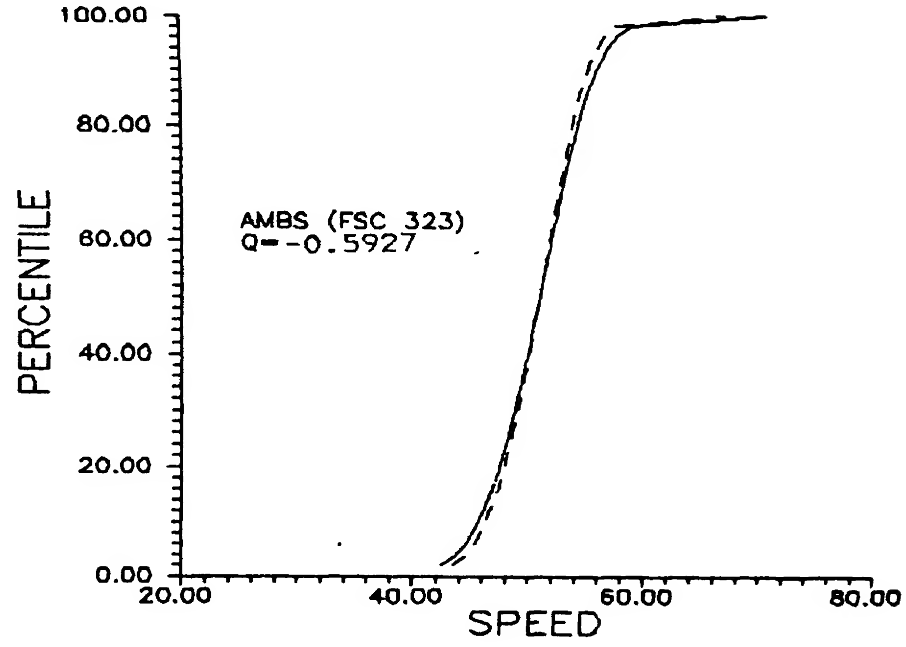
———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

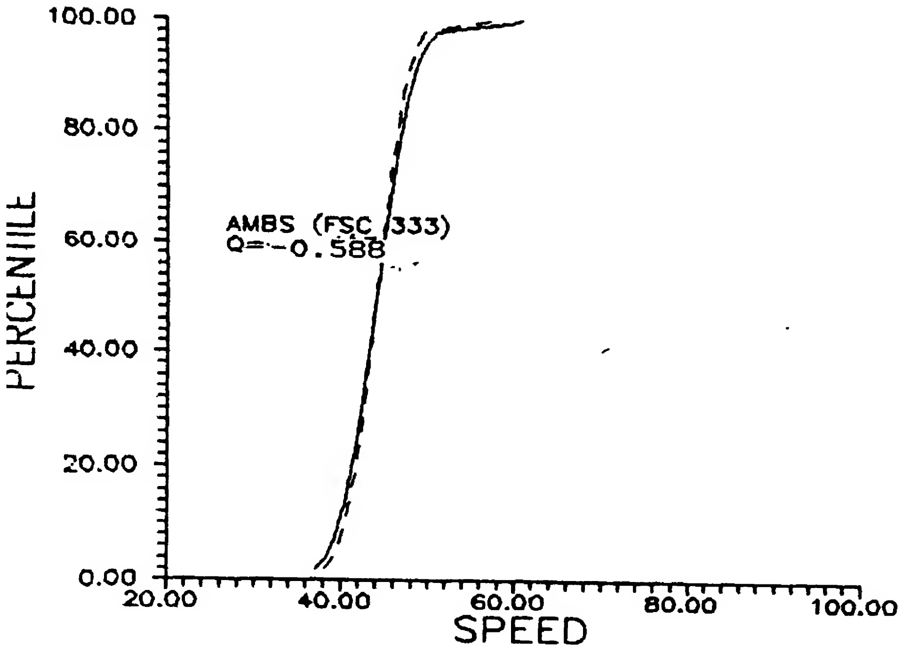
FIG.4.11



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

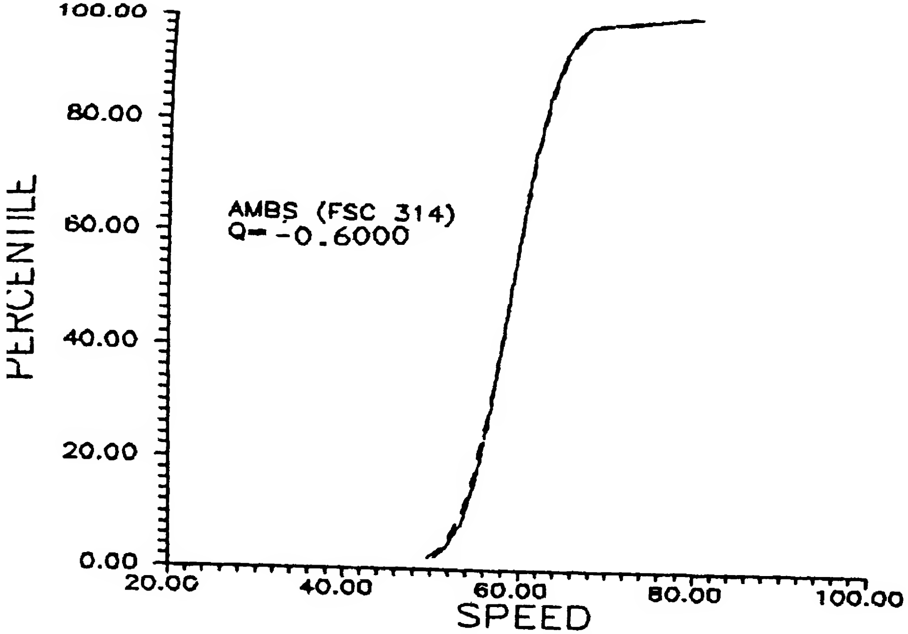
LANE WIDTH:7.0m , TERRAIN :PLAIN

RADIUS OF CURVATURE :BETWEEN 300m AND 450m

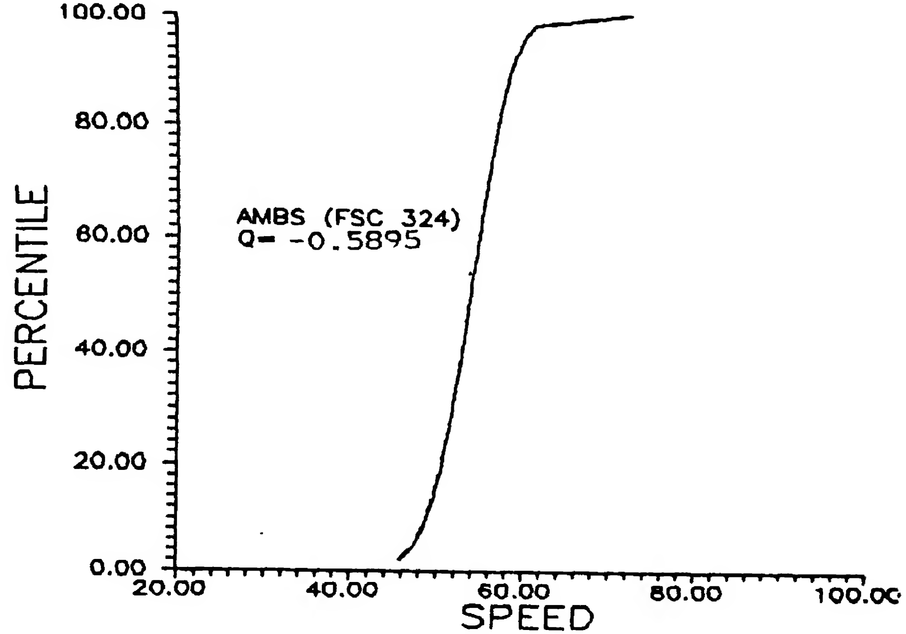
———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

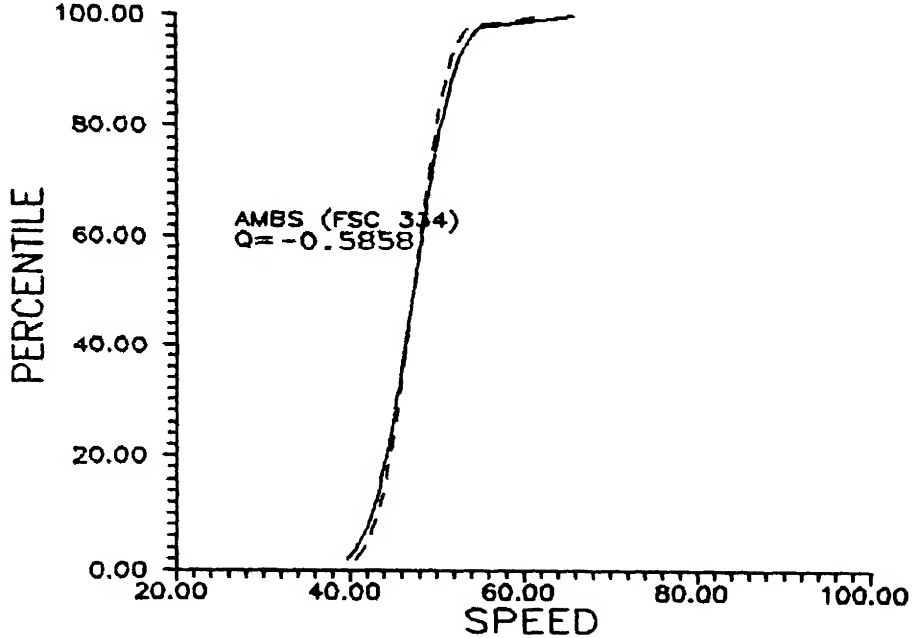
FIG.4.12



ROUGHNESS : LESS THAN 3000 mm/km



ROUGHNESS : BETWWEEN 3000 mm/km TO 6000 mm/km



ROUGHNESS : MORETHAN 6000 mm/km

VEHICLE TYPE : AMBASSADOR

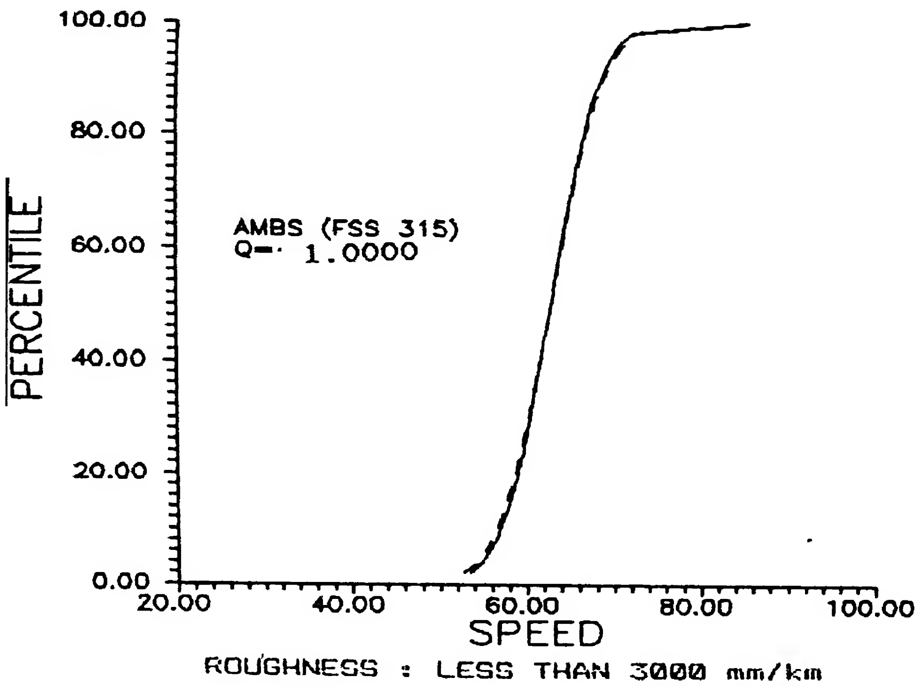
LANE WIDTH: 7.0m (TL) , TERRAIN : PLAIN

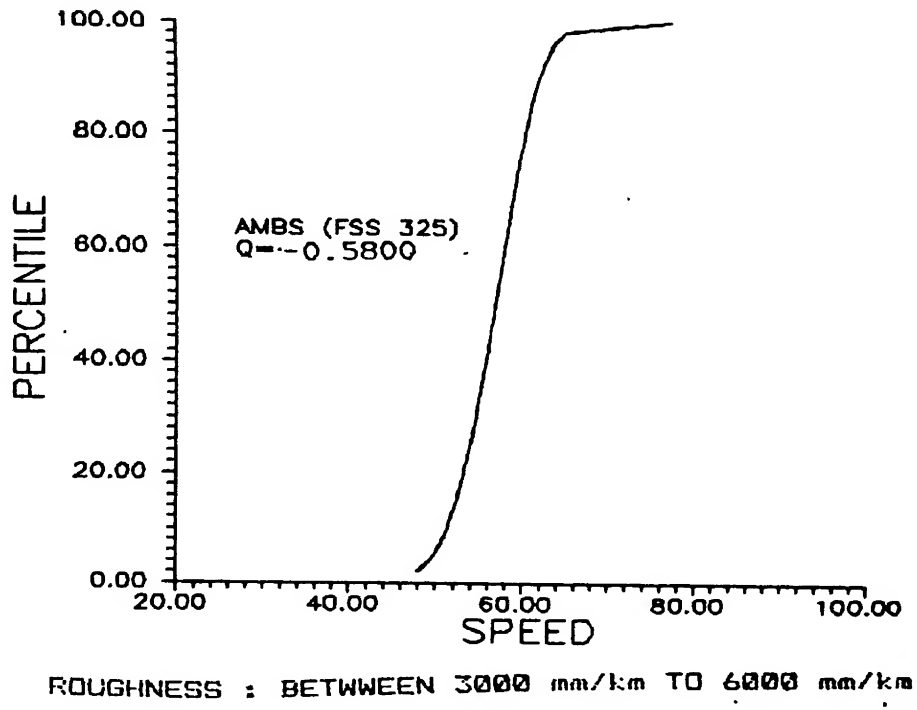
RADIUS OF CURVATURE : BETWEEN 450m AND 1000m

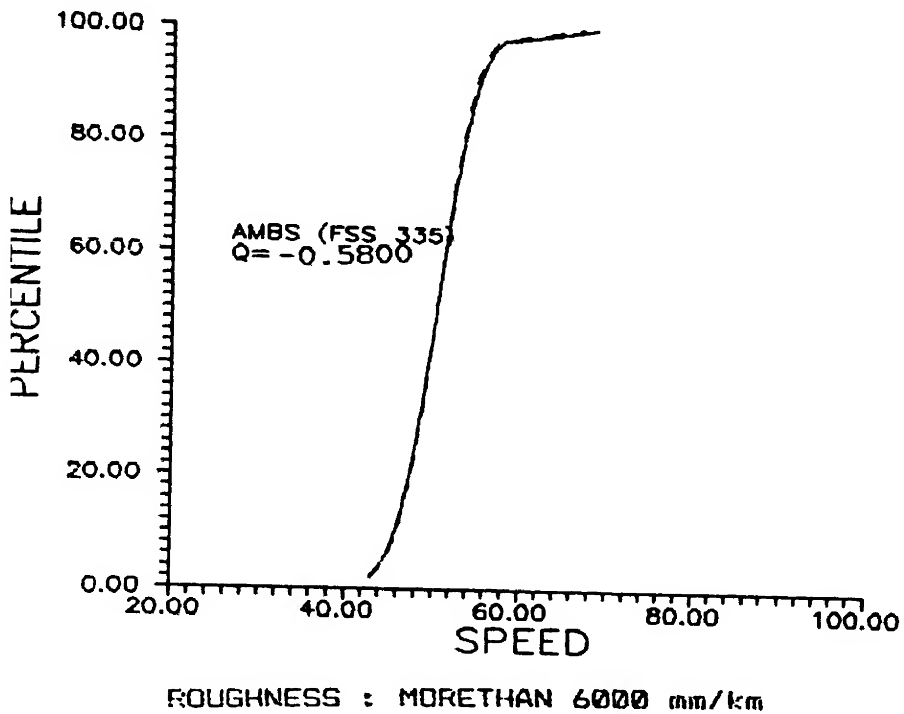
———— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

FIG.4.13







VEHICLE TYPE : AMBASSADOR

LANE WIDTH:7.0m (TL), TERRAIN :PLAIN

RADIUS OF CURVATURE :STRAIGHT ROAD

———————— REPRESENTS FIELD DATA

- - - - - - - REPRESENTS PREDICTED DATA

FIG.4.14

CHAPTER V

VALIDATION OF THE SIMULATION MODEL

5.1 General

Validation involves the verification that the structure of the model is correct and robust with respect to the parameter estimation. Generally the validation of a model is based on an agreement between the output of the model and available information from real life situation if they exist. The close such an agreement, better is the validity of the model. The model can be used to simulate future conditions only after it has been validated and found to replicate the dynamics of the process observed in the real world system under study. Validation thus provides an objective measure for confirmation of the correctness of the submodels along with assumptions involved in framing the model. Submodels like desired speed distributions, overtaking gap acceptance probability etc. that are based on the observed data must be validated separately. Using the overall simulation results, it is necessary to calibrate the values of some of the parameters and decision logics. The overall validation of the simulation model is a test of how well the submodels have been assembled

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into a realistic representation of the system.

5.2 Measure of Effectiveness for Validation

The model outputs to be used as measure of effectiveness in validation should be such that

i) They represent the output of the whole system

ii) They are capable of accurate measurements in the field.

Significant disagreement implies that the model is unsatisfactory. We therefore decided to concentrate on analysis of the difference between the observed and simulated means and standard deviations in order to quantify just how "good" or "bad" the comparisons were.

5.3 Test for Significance Of Difference Between Simulated and Observed Values

Normal statistical procedure specifies the application of Chi square test for significance of difference between the two sets of data. This test is, however considered too stringent for model validation, as intuitively very good fits may also indicate 'significant difference' when subjected to the test. Analysis of difference between observed and simulated values for mean values and standard

deviations for free speed was adopted as a quantitative measure for the purpose.

5.4 Road Test Section for Model Validation :

For the purpose of validation, a hypothetical road stretch of length 4.5 Km and of road block length 200m each were generated. The different geometric feature that are being considered for validation are road width, horizontal curvature and surface roughness. Since the validation of the model have been carried out for free speed conditions, the traffic is generated only in one direction, so that movement of the vehicle is not constraint by the vehicles travelling in the other direction.

5.4.1 Classification According To Roadwidth

In road width category three different types of road width were considered. The three different classifications are

Classification	Name	Road width
I	Single Lane	3.5m
II	Intermediate Lane	5.5m
III	Two Lane	7.0m

5.4.2 Classification According To Horizontal Curvature

All the horizontal curves have been classified into four groups. The classification is done as follows.

Classification	Radius (R)
I	R <= 150m
II	150m < R <= 300m
III	300m < R <= 450m
IV	450m < R <= 1000m

5.4.3 Classification According To Surface Roughness

As far as surface roughness is concerned, the road has been classified into three different groups. First classification consists of all roads having surface roughness less or equal to 3000 mm/km. In the second classification, all the road having roughness between 3000 and 6000 mm/km , are included. All the roads with roughness more than 6000 mm/km are in in the third group.

For the each cell in the measurement matrix, a road file is created satisfying all the geometric combinations of that cell.The input given to the road submodel are, blockborder start coordinate, slope, horizontal curvature, roughness, roadwidth for each block. When road

submodel creates a road file, it computes and assigns median block speed(V_{3m}) and Q value for each vehicle, on each road block of the road stretch to be simulated. The Table 5.1 shows a typical road file created by the road submodel. The Table 5.2 also shows the traffic file given as input to the simulation model. The power mass ratio used for different vehicles are listed in Table 5.3. Thus road files created for each cells of the measurement matrix were given as input to the simulation programme along with the traffic file. Since execution time of the simulation program increases with the increase in vehicle number in the traffic file, we considered only seven vehicle types(Ambassador , Fiat, Maruti, Jeep, Bus,LCV and Truck), and 110 vehicles of each type were generated for each simulation run. After each simulation run, output file (event file) obtained was processed in the statistical submodel and results were tabulated.

5.5 Comparison Of Simulated and Observed Data

Comparison of simulated and observed data for single lane, intermediate lane and two lane roads for different horizontal curvature and roughness is presented in Table 5.1.1 to Table 5.7.3. The analysis of data presented in the tables indicates good agreement between observed and

vehicles studied.The percentage difference of the standard deviation of the mean free speeds were observed to be slightly high. The reason could be that, in the simulation model speed of a vehicle travelling on a particular road block remains constant. Whereas in the field, the speed does not remain constant throughout the block length. The model also gives slightly higher value of the of mean free speed as the radius of horizontal curvature decreases. This is due to the fact that Q value calibrated for cells in the measurement matrix having lesser horizontal curvature does not rotate these distributions as much as it should have been(Ref. Fig.4.1).As a result free speed distributions predicted with these Q value are not very accurate. But in case of larger radius the rotation is perfect and predicted free speed distribution is very close to the field distribution. This is because the standard deviation of the mean free speed does not decrease as much as it should have been as mean free speed decreases. Thus this discrepancy of simulated data and field data on the road stretch having lesser radius of horizontal curvature can be attributed to errors field data collection.

But as a whole, the percentage difference between the mean free speed for all the vehicle types and for all the road combinations were found to be less than 5%,

parameters calibrated are correct.

Thus it can be concluded that model developed is capable of predicting accurately the free speed distribution of vehicles on any road stretches. Next chapter presents the summary of the present work, conclusions and scope for the further work.

TABLE 5.1 ROAD FILE GIVEN AS INPUT TO THE SIMULATION PROGRA

Roadwidth = 7.0m, Radius of curvature = 300m, Roughness = 1500 mm/km

---

```
4      0  1500
4    700  1000
4   1200  1180
4   2044   900
4   2900  1200
4   3450   780
4   4060  1300
4   4510   900
1    0          200
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0   30   0   0   0   1
1   200  400
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0   30   1   1   0   1
1   400  600
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0  14.35 -0.71  15.03 -0.87  17.21 -0.99  13.09 -0.64  12.50 -1.23  12.62 -0.60  14.61 -0.94
0  11.76 -0.43   4.17 -0.42   2.22 -0.40   4.17 -0.40   8.34 -0.42  13.90 -0.41   9.73 -0.41
0   30   1   1   0   1
```

TABLE 5.2 TRAFFIC FILE GIVEN AS INPUT TO THE SIMULATION PROGRAMME

Identity No.	Start Cord.	Dest. Cord.	Veh. Type	Veh. BDS	Cross BDS	p/m Ratio	Entry Time	Entry Speed
1	0	4500	1	18.47	18.47	10.00	25.5	15.7
2	0	4500	8	14.85	14.85	10.18	38.9	12.6
3	0	4500	8	14.62	14.62	2.26	57.9	12.4
4	0	4500	4	16.68	16.68	7.94	68.4	14.2
5	0	4500	4	16.10	16.10	2.50	95.8	13.7
6	0	4500	7	19.81	19.81	3.70	104.0	16.8
7	0	4500	4	16.09	16.09	5.51	185.5	13.7
8	0	4500	8	18.89	18.89	2.64	204.6	16.1
9	0	4500	9	15.35	15.35	3.46	207.0	13.0
10	0	4500	2	18.19	18.19	4.76	213.6	15.5
11	0	4500	4	17.38	17.38	12.70	218.4	14.8
12	0	4500	9	16.91	16.91	4.27	222.8	14.4
13	0	4500	9	16.56	16.56	2.70	245.1	14.1
14	0	4500	1	18.47	18.47	10.00	262.6	15.7
15	0	4500	2	17.02	17.02	8.40	306.5	14.5
16	0	4500	3	22.59	22.59	5.77	317.0	19.2
17	0	4500	2	19.12	19.12	7.00	327.0	16.3
18	0	4500	3	21.52	21.52	6.99	366.3	18.3
19	0	4500	7	15.81	15.81	2.22	417.1	13.4
20	0	4500	7	15.91	15.91	3.20	436.2	13.5
21	0	4500	7	18.04	18.04	3.38	446.8	15.3

TABLE 5.3 POWER MASS RATIO USED IN THE SIMULATION MODEL

POWER TO MASS RATIO	CUMULATIVE PERCENTILE						
	AMBASSADOR	FIAT	MARUTI	JEEP	BUS	LCV	TRUCK
1.0	1.67	1.60	0.00	1.67	0.00	1.67	1.76
2.0	3.90	3.90	0.00	3.90	0.90	3.90	11.76
3.0	8.90	8.89	0.00	8.89	13.30	8.89	35.29
4.0	16.67	16.67	0.00	16.70	61.67	16.70	55.29
5.0	31.10	31.10	0.00	31.10	86.70	31.10	69.41
6.0	44.40	44.40	1.60	44.40	93.30	44.40	80.00
7.0	63.30	63.30	3.90	63.30	98.30	63.30	88.23
8.0	74.40	74.40	16.70	74.40	98.30	74.40	94.11
9.0	83.30	83.30	31.10	83.30	100.00	83.30	98.82
10.0	88.90	88.90	44.40	88.90	100.00	88.90	100.00
11.0	94.40	94.40	63.30	94.40	100.00	94.40	100.00
12.0	95.60	95.60	74.40	95.60	100.00	95.60	100.00
13.0	98.89	98.90	83.30	98.90	100.00	98.90	100.00
14.0	100.00	100.00	88.90	100.00	100.00	100.00	100.00
15.0	100.00	100.00	94.40	100.00	100.00	100.00	100.00
16.0	100.00	100.00	95.60	100.00	100.00	100.00	100.00
17.0	100.00	100.00	98.90	100.00	100.00	100.00	100.00
18.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
19.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
20.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 5.1.1 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: AMBASSADOR CAR LANE: SINGLE (3.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0}$ 100	$\frac{\sigma_1 - \sigma_0}{\sigma_0}$ 100
R <= 300m	46.63	3.78	48.00	3.20	+2.93	-15.46
300M < R <= 450m	50.93	3.78	51.80	2.80	+1.70	-26.03
450 < R <= 1000m	55.23	3.89	54.50	2.80	-1.32	-28.04
STRAIGHT	59.53	3.85	58.00	3.10	-2.57	-19.64

ROUGHNESS :4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0}$ 100	$\frac{\sigma_1 - \sigma_0}{\sigma_0}$ 100
R <= 300m	43.10	3.10	44.60	2.70	+3.48	-13.53
300m < R <= 450m	45.98	3.41	46.80	2.80	+1.78	-18.00
450m < R <= 1000m	48.87	3.64	48.30	2.70	-1.17	-25.90
STRAIGHT	51.75	4.19	51.40	2.90	-0.67	-30.80

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0}$ 100	$\frac{\sigma_1 - \sigma_0}{\sigma_0}$ 100
R <= 300m	37.10	2.676	37.7	1.9	+1.62	-28.90
300m < R <= 450m	39.39	3.207	40.7	2.7	+3.33	-15.80
450m < R <= 1000m	41.68	2.948	41.3	2.3	-0.91	-21.90
STRAIGHT	43.97	3.99	43.6	2.7	-0.84	-23.30

μ_0, μ_1 INDICATES MEAN, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.12 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: AMBASSADOR CAR LANE:INTERMEDIATE (5.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	46.99	3.57	47.80	2.30	+1.73	-35.57
150m < R <= 300m	47.92	3.64	47.60	2.30	-0.66	-36.80
300M < R <= 450m	52.41	4.38	52.00	3.70	-0.78	-13.61
450 < R <= 1000m	56.91	4.40	56.00	3.00	-1.59	-32.58
STRAIGHT	61.41	4.30	58.90	3.90	-4.08	-9.40

ROUGHNESS: 4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	44.06	3.45	46.10	2.20	+4.63	-36.23
150m < R <= 300m	44.96	3.52	45.20	2.70	+0.53	-23.39
300m < R <= 450m	48.14	4.07	47.70	3.20	-0.91	-21.53
450m < R <= 1000m	51.31	4.12	51.10	2.70	-0.41	-34.59
STRAIGHT	54.48	3.68	53.90	2.80	-1.06	-24.01

ROUGHNESS :7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	38.85	3.16	38.50	1.70	-0.90	-46.20
150m < R <= 300m	38.58	3.13	38.90	2.10	+0.82	-33.07
300m < R <= 450m	41.57	2.68	41.90	1.90	+0.79	-29.26
450m < R <= 1000m	44.56	3.40	44.90	2.50	+0.76	-26.57
STRAIGHT	47.55	3.50	47.10	2.30	-0.95	-34.43

μ_0, μ_1 INDICATES MEAN SPEED IN KMPH, σ_0,σ_1 INDICATES STANDARD DEVIATION .

TABLE 5.1.3

COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: AMBASSADOR CAR   LANE:TWO(7.0m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	σ_0	SIMULATED DATA μ_1	σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	50.21	3.71	51.60	2.70	+2.76	-27.20
150m < R <= 300m	51.61	3.81	51.30	2.60	-0.60	-31.90
300M < R <= 450m	55.35	3.97	54.60	2.90	-1.35	-27.08
450 < R <= 1000m	59.09	4.21	57.70	3.10	-2.35	-26.43
STRAIGHT	62.82	4.54	59.30	3.70	-5.60	-18.62

ROUGHNESS:4500 mm/km

HORIZONTAL CURVE	μ_0	σ_0	μ_1	σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	46.66	3.46	47.70	2.40	+2.22	-30.63
150m < R <= 300m	47.99	3.55	47.20	2.40	-1.64	-32.54
300m < R <= 450m	50.88	4.07	50.40	3.20	-0.94	-21.45
450m < R <= 1000m	53.77	3.81	53.30	2.90	-0.87	-23.88
STRAIGHT	56.67	4.20	55.80	3.00	-1.53	-28.62

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	μ_0	σ_0	μ_1	σ_1	$\frac{\mu_1-\mu_0}{\mu_0}$ 100	$\frac{\sigma_1-\sigma_0}{\sigma_0}$ 100
R <= 150m	41.45	2.67	40.80	1.80	-1.56	-32.58
150m < R <= 300m	40.90	2.63	41.10	1.80	+0.50	-31.55
300m < R <= 450m	44.11	3.35	44.70	2.70	+1.34	-19.45
450m < R <= 1000m	47.31	3.71	47.10	2.40	-0.44	-35.44
STRAIGHT	50.51	3.66	50.20	2.60	-0.61	-29.13

μ_0, μ_1 INDICATES MEAN SPEED IN KMPH, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.3.1 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: MARUTI CAR LANE: SINGLE(3.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}100$	$\frac{\sigma_1-\sigma_0}{\sigma_0}100$
R <= 300m	54.65	4.93	55.50	3.40	+1.55	-31.10
300M < R <= 450m	59.25	4.93	58.30	3.40	-1.60	-31.00
450 < R <= 1000m	63.85	4.72	63.20	3.80	-1.02	-19.57
STRAIGHT	68.45	5.77	68.10	4.70	-0.51	-18.65

ROUGHNESS: 4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}100$	$\frac{\sigma_1-\sigma_0}{\sigma_0}100$
R <= 300m	49.41	4.36	51.30	3.60	+3.82	-17.60
300m < R <= 450m	53.44	4.87	52.20	3.60	-2.32	-26.16
450m < R <= 1000m	57.47	4.69	57.80	3.20	+0.57	-31.88
STRAIGHT	61.51	4.86	61.90	3.60	+0.65	-25.92

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1-\mu_0}{\mu_0}100$	$\frac{\sigma_1-\sigma_0}{\sigma_0}100$
R <= 300m	41.84	3.33	41.20	2.80	-1.53	-16.06
300m < R <= 450m	46.08	4.04	44.70	3.00	-2.99	-25.79
450m < R <= 1000m	50.32	4.52	50.90	3.70	+1.15	-18.17
STRAIGHT	54.56	4.90	55.60	3.20	+1.91	-34.70

μ_0, μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.3.2 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: MARUTI CAR LANE: INTERMEDIATE(5.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 15000 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} X100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} X100$
R <= 150m	56.48	4.30	56.90	3.60	+0.74	-16.27
150m < R <= 300m	57.20	4.35	56.90	3.60	-0.52	-17.33
300M < R <= 450m	61.80	4.87	62.20	3.50	+0.64	-28.19
450 < R <= 1000m	66.39	5.58	66.80	4.10	+0.62	-26.56
STRAIGHT	70.98	5.91	70.50	4.80	-0.67	-18.83

ROUGHNESS: 4500 mm/km

R <= 150m	52.59	4.550	55.0	3.4	+4.58	-25.27
150m < R <= 300m	53.37	4.617	53.8	3.2	+0.80	-30.69
300m < R <= 450m	56.97	4.629	57.4	3.3	+0.75	-28.71
450m < R <= 1000m	60.56	4.704	60.8	3.6	+0.40	-23.46
STRAIGHT	64.16	4.749	64.5	3.9	+0.53	-17.87

ROUGHNESS :7500 mm/km

R <= 150m	44.90	3.940	44.1	2.3	-1.12	-41.62
150m < R <= 300m	44.17	3.875	44.8	3.1	+1.42	-20.00
300m < R <= 450m	48.56	1.133	49.1	2.6	+1.11	-37.09
450m < R <= 1000m	52.95	4.551	53.2	3.0	+0.47	-34.00
STRAIGHT	57.34	4.400	57.8	3.3	+0.80	-25.00

μ_0 ,μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.3.3 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: MARUTI CAR LANE:TWO(7.0m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} X100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} X100$
R <= 150m	60.98	4.66	62.80	4.50	+2.98	-3.43
150m < R <= 300m	61.92	4.31	62.30	3.60	+0.61	-23.90
300M < R <= 450m	65.57	5.11	65.90	3.60	+0.50	-21.72
450 < R <= 1000m	69.11	5.74	69.80	4.40	+0.83	-23.43
STRAIGHT	72.87	5.96	72.20	4.90	-0.92	-17.85

ROUGHNESS: 4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} X100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} X100$
R <= 150m	54.32	4.88	55.70	3.50	+2.54	-28.27
150m < R <= 300m	55.92	5.02	56.20	3.20	+0.50	-36.29
300m < R <= 450m	59.54	4.54	59.80	3.50	+0.43	-22.92
450m < R <= 1000m	63.17	4.75	63.40	3.80	+0.36	-20.03
STRAIGHT	66.79	5.59	66.90	4.20	+0.26	-24.91

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} X100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} X100$
R <= 150m	48.41	4.26	47.90	2.70	-1.05	-36.62
150m < R <= 300m	48.11	4.23	48.70	3.20	+1.22	-24.40
300m < R <= 450m	52.31	4.37	52.70	3.10	+0.74	-28.19
450m < R <= 1000m	56.51	4.59	56.80	3.20	+0.51	-29.96
STRAIGHT	60.71	5.01	61.00	3.60	+0.50	-26.00

μ_0, μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.7.1 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: TRUCK LANE: SINGLE(3.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\mu_0} \times 100$
R <= 300m	39.83	3.26	38.4	2.80	-3.59	-14.21
300M < R <= 450m	45.75	3.26	45.0	2.60	-1.63	-20.34
450 < R <= 1000m	51.66	3.89	50.3	3.20	-2.63	-17.86
STRAIGHT	57.57	4.73	55.3	4.10	-3.94	-13.37

ROUGHNESS: 4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\mu_0} \times 100$
R <= 300m	38.72	3.18	39.20	2.50	+1.23	-21.40
300m < R <= 450m	42.39	3.07	41.90	2.40	-1.15	-22.05
450m < R <= 1000m	46.06	3.19	45.30	2.70	-1.65	-15.36
STRAIGHT	49.74	3.82	48.60	3.00	-2.29	-21.56

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\mu_0} \times 100$
R <= 300m	32.86	2.64	32.50	1.90	-1.95	-28.24
300m < R <= 450m	35.87	3.13	35.40	2.80	-1.31	-10.68
450m < R <= 1000m	38.89	2.81	38.40	2.10	-1.25	-25.40
STRAIGHT	41.91	3.01	41.40	2.40	-1.21	-20.42

μ_0, μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.7.2 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: TRUCK LANE: INTERMEDIATE(5.5m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} \times 100$
R <= 150m	43.04	3.24	41.90	2.40	-2.65	-25.92
150m < R <= 300m	42.84	3.22	42.00	2.40	-1.96	-25.50
300M < R <= 450m	48.28	4.05	47.30	2.80	-2.03	-30.91
450 < R <= 1000m	53.73	4.45	52.10	3.60	-3.03	-19.13
STRAIGHT	59.18	4.28	56.50	4.40	-4.52	+2.71

ROUGHNESS: 4500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} \times 100$
R <= 150m	40.37	3.36	41.00	2.30	+1.56	-31.54
150m < R <= 300m	40.66	3.38	40.20	2.30	-1.13	-32.01
300m < R <= 450m	44.22	3.65	43.50	2.50	-1.62	-31.60
450m < R <= 1000m	47.78	3.76	46.80	2.80	-2.05	-25.60
STRAIGHT	51.34	3.79	50.00	3.20	-2.61	-15.72

ROUGHNESS: 7500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0} \times 100$	$\frac{\sigma_1 - \sigma_0}{\sigma_0} \times 100$
R <= 150m	35.31	3.07	34.40	1.80	-2.58	-41.36
150m < R <= 300m	34.74	3.02	34.20	2.20	-1.55	-27.15
300m < R <= 450m	37.66	2.81	37.20	2.10	-1.22	-25.34
450m < R <= 1000m	40.58	3.26	40.10	2.20	-1.18	-32.50
STRAIGHT	43.50	3.32	42.80	2.50	-1.61	-24.78

μ_0, μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

TABLE 5.7.3 COMPARISON OF SIMULATED AND FIELD DATA

VEHICLE TYPE: TRUCK LANE: TWO(7.0m)

NUMBER OF VEHICLE SIMULATED: 110

ROUGHNESS: 1500 mm/km

HORIZONTAL CURVE	FIELD DATA μ_0	FIELD DATA σ_0	SIMULATED DATA μ_1	SIMULATED DATA σ_1	$\frac{\mu_1 - \mu_0}{\mu_0}$X100	$\frac{\sigma_1 - \sigma_0}{\sigma_0}$X100
R <= 150m	45.77	3.17	45.40	2.70	-0.81	-14.80
150m < R <= 300m	46.24	3.20	45.50	2.20	-1.60	-15.67
300M < R <= 450m	50.96	3.57	49.70	3.20	-2.47	-19.13
450 < R <= 1000m	55.67	3.99	53.80	3.90	-3.35	- 2.40
STRAIGHT	60.38	4.16	57.40	4.50	-4.93	+8.12

ROUGHNESS: 4500 mm/km

R <= 150m	42.67	3.10	42.60	2.50	-0.35	-17.64
150m < R <= 300m	43.36	3.15	42.90	2.50	-1.06	-20.63
300m < R <= 450m	46.63	3.57	45.70	2.70	-1.99	-24.55
450m < R <= 1000m	49.90	3.81	48.70	3.00	-2.40	-21.30
STRAIGHT	53.17	4.29	51.70	3.50	-2.76	-18.54

ROUGHNESS: 7500 mm/km

R <= 150m	37.68	2.79	36.70	2.00	-2.60	-28.31
150m < R <= 300m	36.79	2.72	37.00	2.00	+0.57	-26.70
300m < R <= 450m	39.84	3.20	39.50	2.20	-0.85	-31.33
450m < R <= 1000m	42.90	2.82	42.30	2.50	-1.39	-11.37
STRAIGHT	45.96	3.11	45.20	2.70	-1.65	-13.43

μ_0, μ_1 INDICATES MEAN SPEED, σ_0, σ_1 INDICATES STANDARD DEVIATION

CHAPTER VI

SUMMARY CONCLUSION AND SCOPE FOR FURTHER WORK

6.1 Summary

The primary objective of this thesis is to calibrate all the parameters involving free vehiclre model, form the field data collected by CRRI. The road submodel is then modified and finally traffic simulation model is extensively validated for free vehicle speed.

As far as calibration of the parameters are concernrd, Q value which is the total transformation measure of basic median speed V_{0m} to the median speed V_{3m}, is calibrated for ten different vehicle types. The total measure of rotation Q is also a function of q_i (q1 for road width, q2 for horizontal curvature and q3 for surface roughness) with median speeds V_{1m}, V_{2m} and V_{3m} included as weighing factor. Thus in order to calibrate Q value , q_i values were calibrated first and then weighing factor α_i values were calibrated. Using the calibrated Q value, distribution of the speed about the median value V_{3m}, termed as speed distribution of the desired speed were generated. The generated distributions were then compared with actual

distribution of the desired speed were generated. The generated distributions were then compared with actual distribution, and found satisfactory.

Once the Q value is calibrated, it is implemented into the road submodel of the simulation model. Then hypothetical road stretch of 4.5 km. long, satisfying all the geometric combinations of each and every cell of the measurement matrix (as shown in Table 3.1) is generated. The simulation program is then run using the generated road as input and simultion result is then compared with field data. The percentage difference between simulated and field data were found to be less than 5% for each cell.

6.2 Conclusion

From the calibrated model we can evaluate the mean free speed of each vehicle type when moving under free condition. The results show a clear trend of decrease in the mean free speed as the road width decreases. The results also show that as the radius of horizontal curvature decreases, the mean speed decreases. The mean speed also decreases as the surface roughness increases. It is also observed that the

vehicle type like Maruti, which has higher power mass ratio has higher mean speed than the vehicle with lower power mass ratio like trucks. Hence it can be concluded that the results are consistent with respect to calibrated parameters.

6.3 Scope for Further Work

The traffic simulation model presented herein have covered much needed new ground in respect of both traffic and road parameters, and may be taken to mark an effective begining in simulation modeling for heterogeneous traffic on narrow road condition. Further work that may be considered are

1. Calibration and validation of interaction model

2. Intersections, involving deceleration and acceleration of vehicles.

3. Signalized intersections, involving the halt-proceed operations for vehicles.

4. Bus-stop obstructions on narrow roads.

5. Shoulder width, type and quality can be explicitlytaken into account and their effect on free speed can be obtained using the similar procedures given in this thesis. In this respect it is also worthwhile to predict the effect of wet shoulder as against dry shoulder.

6. Environmantal conditions such as the inclemental weather conditions can be also studied.

7. Free speeds were measured only during day time on the sample of roads used in this study. Since a large percentage of vehicles namely trucks and buses are found to operate at night it is desirable to study the free speeds of these vehicles at night. This is all the more important as there are a number of accedients taking place during night. There are numerous roadway factors affecting the speed of vehicles at night and for effecient traffic operations it is important to identify these factors and incorporate in design

and maintenance phases of the roads.To achive this night vision cameras may be required with inbuilt infrared optical system.

REFERENCES

1. Brodin,A. and Palaniswamy, S.P., (1985) "A Generalized Simulation Model - A program for the Monte Carlo Simulation of Heterogeneous Vehicle Traffic along Single, Intermediate and Narrow Two Lane Roads: An Application of JSP and Simila-67". Communication 439A, VTI, Linkoping, Sweden.

2. Gilliam, C. D., "A Model For the Generation of Various Traffic Characteristics". MAU note, DTp (1976)

3. Brodin, A., Carlsson, A., " The VTI Traffic Simulation Model - A description of Model and Program Systems". Communication 321A, VTI, Linkoping, Sweden.

4. Brodin, A.., Gynnerstedt, G. A., (1979) "Program for the Monte Carlo Simulation Of Vehicle Traffic along Two Lane Rural Roads". Communication 143, VTI, Linkoping, Sweden.

5. CRRI (1985), " Traffic Simulation Modeling Study: Part I, 'Developments of Models' ", Central Road Research Institute, New Delhi, India.

6. CRRI (1985) "Traffic Simulation Modeling Study: Part II 'User Manual and Computer Program' ", Central Road Research Institute, New Delhi, India.

7. Palaniswamy, S.P. (1983), "A Generalized Simulation Model for Vehicular Behaviour Under Heterogeneous Traffic Conditions". Indo-Swedish Traffic Simulation Research Project, IIT Kanpur, India.

8. Palaniswamy, S.P., Gynnersdett, G., and Phull, Y.R. (1985), "Indo-Swedish Road Traffic Simulation Model: Generalized Traffic System Simulator". Transportation Research Record 1005.

9. Gilliam, C. D., and Johnsen, S. (1979) "Validation of the Swedish Traffic Simulation Model for U.K. Road and Traffic Conditions". EH Division, DTp.

10. CRRI (1992), "Development and Application of Traffic Simulation Models: 'Free Speed Study' ", Central Road Research Institute, New Delhi, India.

11. Mitrani, I. (1982), "Simulation Techniques for Discrete Event System", Combridge University Press.

12. Chalapati, M.V., "Simulation of Multilane Undirectional Traffic" Ph.D. Thesis, Indian Institute of Technology, Kanpur, India.

13. Nageswara Rao, A., " Traffic Flow Simulation and Estimationof Road User Cost on Indian Road Network ". M.Tech Thesis, Indian Institute of Technology, Kanpur, India.